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A BANNED BROADCAST

By the same Author

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POSSIBLE WORLDS *and Other Essays*
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KEEPING COOL *and Other Essays*
THE CAUSES OF EVOLUTION
ENZYMES
DAEDALUS, *Or Science and the Future*
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FACT AND FAITH
MY FRIEND MR LEAKEY
ANIMAL BIOLOGY; with J. S. Huxley
A.R.P.
SCIENCE AND EVERYDAY LIFE
HEREDITY AND POLITICS
THE MARXIST PHILOSOPHY AND THE SCIENCES

A
Banned Broadcast

AND OTHER ESSAYS

by

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1946

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PREFACE

MOST of the essays here reprinted were first published in the *Daily Worker*, for which I write a weekly article on some scientific topic. The five on dialectical materialism were published in the *Labour Monthly*. "I was a Biometrician", and "The Universe gets less Mysterious" appeared in the *New Statesman*, "The Laws of Nature", "Cleomenes and Christ", and "The Argument from Design" in the *Rationalist Annual*, and "How to write a Popular Scientific Article" in the *Journal of the Association of Scientific Workers*. The places of publication of others are acknowledged in the body of the book.

They cover a wide period of time, and some of them are no longer topical. I hope, for example, that the article on "Air Raid Noises" will be wholly out of date by the time this book is published. I have changed my opinions since some of them were written. If I had not this would merely prove that I had ceased to learn from experience. I have also made some mistakes as to what was likely to happen. It would obviously have been unfair to correct them after the event.

But even when air raids are no more than an unpleasant memory, they will furnish a more vivid exposition of some of the principles of probability than does the drawing of black-and-white balls from bags. And though Lord Birkenhead is dead, it is worth pointing out that a Lord Chancellor can be dishonest.

If some readers complain that I have not covered so wide a field as in former books, my excuse must be that some of the most interesting developments of science are official secrets, and that the flow of scientific publication has been greatly diminished by the war. But the war has at least convinced hundreds of thousands of people that they must take science seriously. And an appreciable fraction of these believe, with me, that scientific method can be applied to history, economics and politics. My main object in publishing this volume is to increase their number.

J. B. S. HALDANE

October 1944.

CONTENTS

page

Preface v

1. *PERSONAL*

How to write a Popular Scientific Article 3
I am not a Magician 9
Lord Birkenhead improves his Mind 13
A Banned Broadcast 18
I was a Biometrician 26
My War Job 31
What I am Fighting For 37

2. *THE UNIVERSE*

What is Matter? 43
The Universe gets less Mysterious 47
The Laws of Nature 53
Cleomenes and Christ 60
The Argument from Design 67
Planets of Other Suns 73
Mr. Bolfry and the Sun 76
Naming the Stars 79

3. *MATHEMATICS*

Machines that Think 85
Measuring Time 88
A.R.P. Fallacies 92
Samples 96
Statistics 99
More About Statistics 103
Millions 107
Infinity 110
The Differential Calculus 114

4. *LOGIC*

Logic 119
Induction and Deduction 123
What "Hot" Means 127
What "Hard" Means 130

page
Control Experiments 133
Adventures of Words 136
What Use is Philosophy? 139
Is Psychology a Science? 142

5. *SCIENCE AND WAR*
Air Raid Noises 147
Seeing in the Black-out 151
Death Rays 154
The Commonest Poison Gas 158
Will Hitler use Gas? 162
The Physiology of Flying 165
"G" 168
Doodlebugs 171
Blast 174
Probability in War and Peace 177
Ice Ages and Modern History 180
Coral Reefs 183

6. *SCIENCE IN A WORLD COMMUNITY*
I. A World Geological Survey 189
II. A World Biological Survey 191
III. Power 195
IV. Food 197

7. *THE COMPARATIVE STUDY OF FREEDOM* 205

8. *DIALECTICAL MATERIALISM AND MODERN SCIENCE*
I. Everything has a History 235
II. The Unity of Opposites 239
III. Quantity and Quality 244
IV. Negation of the Negation 249
V. Materialism and its Opponents 253

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PERSONAL

How to write a Popular Scientific Article

MOST scientific workers desire to spread a knowledge of their subject and to increase their own incomes. Both can be done by writing on science for the general public. If one can sell the article abroad, one can also be an "invisible export". In what follows I shall give some hints on how to do it. But let no reader suppose that my method is the only one. Literary synthesis is like organic chemical synthesis. The method to be adopted depends on the product required, the raw materials, and the apparatus available. As my brain is my apparatus, and different from yours, my methods will also differ from yours.

The first thing to remember is that your task is not easy, and will be impossible if you despise technique. For literature has its technique, like science, and unless you set yourself a fairly high standard you will get nowhere. So don't expect to succeed at your first, or even your second, attempt.

For whom are you writing? This is even more important than the choice of subject. For you will not get an article on the history of 18th-century physics into a daily newspaper. *The Times* is unlikely to publish a sympathetic account of Soviet work on mineralogy, nor the *Daily Worker* a highly commendatory report on cotton breeding in the British Sudan.[1] Moreover the length of your article will depend on where it is to be published.

Now for the subject matter. You may take a particular piece of research work, or a particular application of science. Or you may choose some general principle, and illustrate it from different branches of scientific work. For example an excellent article could be written on fruitful accidents. Priestley broke a thermometer, and the fate of the mercury from it led him to the discovery of oxygen. Takamine spilled some ammonia into a preparation from suprarenal glands, and crystallized out adrenaline. Probably you will do better to begin on some more specialized topic, unless you are a student of the history of science.

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[1] *The Times* has since changed its policy. But unfortunately the Sudan is still some way behind Peru, the U.S.A., the U.S.S.R. and the West Indies in cotton breeding.

Remember that your treatment of it must be highly selective. So far you have probably written two main types of article. Firstly answers to examination questions in which you tried to show how much you knew about some topic. And secondly scientific papers or technical reports which dealt very exhaustively with a small point. Now you have to do something quite different. You are not trying to show off; nor are you aiming at such accuracy that your readers will be able to carry out some operation. You want to interest or even excite them, but not to give them complete information.

You must therefore know a very great deal more about your subject than you put on paper. Out of this you must choose the items which will make a coherent story. A number of the articles which are submitted to me from time to time are far too like examination answers. They give the impression that the author has looked his subject up, and tried to give a condensed summary of it. Such a summary may be all very well in a text-book, but will not hold the attention of a reader of popular articles, who does not contemplate severe intellectual exertion.

This does not mean that you must write for an audience of fools. It means that you must constantly be returning from the unfamiliar facts of science to the familiar facts of everyday experience. It is good to start from a known fact, say a bomb explosion, a bird's song, or a cheese. This will enable you to illustrate some scientific principle. But here again take a familiar analogy. Compare the production of hot gas in the bomb to that of steam in a kettle, the changes which occur in the bird each year to those which take place in men once in a lifetime at puberty, the precipitation of casein by calcium salts to the formation of soap suds. If you know enough, you will be able to proceed to your goal in a series of hops rather than a single long jump.

If you try to write an article in this way, you will probably discover your own ignorance, especially of quantitative matters. How completely do a robin's gonads revert to an infantile condition in autumn? How much more calcium is there in milk than in London tap water? What is the maximum temperature in an exploding bomb? It may take you twelve hours' reading to produce an intellectually honest article of a thousand words. In fact you will have to educate yourself as well as your public.

When you have done your article, give it to a friend, if possible a fairly ignorant one. Or put it away for six months and see if you still understand it yourself. You will probably find that some of the sentences which seemed simple when you wrote them, now appear very involved. Here are some hints on combing them out. (Remember, by the way, that I am only giving my personal opinions. Prof. Hogben writes sentences longer than some of my paragraphs, and his books sell very well, as they ought to.) Can you get in a full stop instead of a comma or a semicolon? If so, get it in. It gives your reader a chance to draw his breath. Can you use an active verb instead of a passive verb or a verbal noun? If so, use it. Instead of "It is often thought that open windows are good for health", or "There is a widespread opinion that open windows are good for health," try " Many people think that open windows are good for health". Or "Most people", if you think that is the case.

Try to make the order of the phrases in your sentence correspond with the temporal or causal order of the facts with which you deal. Instead of "Species change because of the survival of the fittest" try "The fittest members survive in each generation, and so a species changes". Not that I like the phrase "a species changes". It would be better to say "the average characters of the members of a species, such as weight or hair-length, change". Of course in the history of scientific discovery an effect is commonly known before its cause. And fairly often a mathematical theorem is known to be probably true before it is formally proved. If you enunciate your theorem before you prove it you are apt to give the impression, as Euclid does, that you are producing rabbits from a hat.

Whereas if you lead up to it gently you create less impression of cleverness, but your reader may find your argument much easier to follow.

In a scientific, and still more, a mathematical paper, elegance of presentation, which often means the hat-and-rabbit method, is always great fun, and sometimes desirable. How delightful to produce some wholly unexpected function at the last moment by contour integration, to damn a suggested mechanism by an appeal to Hearnshaw's theorem, or to label a plant which won't breed true as just another case of balanced lethals. By doing so you may help the serious student to short cuts in thinking. But you will merely dazzle the ordinary reader. Go slow, and show him as many steps as you can in your argument or causal chain, even if, in your own thinking, you skip some of them or take them backwards.

When you have written your article it may seem rather gaunt and forbidding, a catalogue of hard facts and abstract arguments. A critic may say it needs padding. I object to padding for padding's sake. It is characteristic of writers who are more interested in their style than their subject matter, such as Charles Lamb or Robert Lynd, but out of place in a scientific article. On the other hand you must do what you can to help your reader to link up your article with the rest of his knowledge. You can do this by referring to familiar facts or to familiar literature. I have been severely criticized for "dragging in" references to Marx in my articles in the *Daily Worker*, though I think I refer to Engels more frequently. But a number of my readers are familiar with the works of these authors. Engels said certain things about change, as Heraclitus said very similar things before him, and Bergson and Whitehead after him. But for one of my readers who has read Heraclitus, Bergson, or Whitehead, a hundred have read Engels, so I prefer to cite him. If I were lecturing on the same matters to classical scholars I should perhaps cite Heraclitus, even though I think Engels said it better.

In my last book on genetics,[1] there are seven quotations from Dante's *Divine Comedy*. I have been criticized for "dragging in" Dante. But I think it worth while to show the continuity of human thought. I don't agree with Dante's theory that mutations are due to divine providence, but I consider it desirable to point out that he had a theory on this subject. I think that popular science can be of real value by emphasizing the unity of human knowledge and endeavour, at their best. This fact is hardly stressed at all in the ordinary teaching of science, and good popular science should correct this fault, both by showing how science is created by technology and creates it, and by showing the relation between scientific and other forms of thought.

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[1] *New Paths in Genetics*. Allen and Unwin, 1941.

A popular scientific article should, where possible, include some news. I try, as a general rule, to include one or two facts which will not be familiar to a student taking a university honours course in the subject in question, unless his teachers keep well up with the periodical literature. As there is often a lag of five years between the publication of a discovery and its inclusion in a textbook, this is not very difficult in peace time. But it is not very easy at present, in view of the number of libraries which have closed down, and the absence of many European and some American periodicals. Of course some care is needed in appraising new work. A very large number of alleged discoveries are not confirmed by subsequent workers. One well-known English popularizer of science has a perfect genius for picking out discoveries of this kind for announcement to the public. If, like myself, the writer is actually engaged in research, and has seen a number of his own bright ideas go west, he is less likely to fall into this particular trap.

In the early stages of popular writing it is well to write out a summary of the article, though I rarely do so myself. Here is a possible skeleton for an article on cheese.

Introduction. A well-known fact, say the shortage of cheese.[1]

Central theme. The process of cheese manufacture.

Why it is important. Cheese as the cheapest food containing large amounts of "good" protein. Vitamins and calcium in cheese.

Connections with other branches of science. Rennet compared with other enzyme preparations used in industry, *e.g.* in confectionery and tanning. Other uses of specific micro-organisms, *e.g.* in brewing. Why putrid cheese is safer than putrid meat.

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[1] This has lessened since this article was written.

Practical suggestions. How to increase our cheese output. Combating mastitis in cows. Cattle feed and fertilizers. Should cargo space be devoted to cheese rather than meat? Need for scientific planning of national food supply.

How much of this you can get in depends on the length of your article and your capacity for compression. If you are writing for a highbrow journal you may quote the passages on cheese from Euripides' *Cyclops*, if for a lowbrow, any of the jokes about the smell of cheese.

That is one way of doing it. But other writers would show cheese as part of the Mysterious Universe. We do not understand protein synthesis, nor the extreme specificity of some enzyme actions. Cheese-making is part of the pre-scientific activities by which we still keep a communion with nature. Cheese is a natural food, and beef is not. And so on. I think this is an anti-scientific attitude. But you can sell that sort of stuff, and get over a certain amount of genuine knowledge while doing so. Everyone must write popular scientific articles in his own way. I have only described one way, and I do not claim that it is the only way, or even the best possible way.

I am not a Magician

AMONG the letters which I receive from readers are a large number asking advice on matters of health, and others making suggestions concerning aerial defence. I am hardly ever able to give a satisfactory answer, and no doubt my correspondents form a low opinion of my powers.

This is because they expect the impossible from me. That is not their fault, but that of the people who write the scientific books and articles which they read. The heroes of popular "scientific" romances invent machines with which they destroy whole armies, lead expeditions to Mars, or create living beings out of laboratory chemicals.

Mr. H. G. Wells bears some blame for this state of affairs. A generation ago he did a great deal to popularize science. But in doing so he told some wildly improbable stories. Mr. Cavor produced a substance which would screen off gravitation, and reached the moon on his first attempt. A chemical change in the atmosphere made everyone behave sensibly. A single air raid across the Atlantic almost wiped out New York, and so on. What is wrong in such stories is that they are idealistic. Once you get the right idea, it is supposed that you can achieve stupendous results very quickly. As a matter of fact science never advances in this way. A new idea, like the theory of chemical atoms, of natural selection, or of relativity, may make what is miscalled an intellectual revolution, that is to say change the ideas of a few thousand specialists.

But even the intellectual changes take a long time to reach the masses. Darwin published his theory eighty years ago, but it is not yet taught in British elementary schools, though it is in those of the Soviet Union. Very few non-specialists understand the theory of relativity, though the "special theory" as it is called, is not very difficult.

And the practical application of science generally takes a long time, partly because of the great differences between laboratory and factory practice, and partly because of the opposition of vested interests. A chemist may be quite satisfied if he gets some new substance in a twentieth of the amount which is theoretically possible. It is much better to waste some of the materials from which he starts, rather than spend a year in determining what conditions give the highest yield. But this is very necessary if the chemical is to be made on a large scale. Moreover the best method in a laboratory is not necessarily the best in a factory.

In a physical laboratory a researcher is delighted if he finally gets an apparatus to work, either to demonstrate a new principle, or to measure something more accurately than before, after many months of experiments which did not give satisfactory results. Later on the apparatus may generally work when it is meant to, but may require several days reconditioning after each time it is used for an hour. It has taken half a century to make X-ray apparatus which will work as regularly as an ordinary photographic camera.

A biologist working with a strain of mice whose females develop cancer of the breast in old age is able to reduce the frequency of cancer to a small fraction by feeding them from birth on milk of a non-cancerous strain. But we do not know if the same principle holds for human cancer, nor are we likely to for many years. And if we did, it would take several generations to apply it in practice.

The "pure" scientist in his laboratory is sometimes an extremely skilled manual worker, making his own apparatus. Sometimes he employs a skilled worker to make it for him. But the apparatus is often very fragile, and wholly unsuited for factory work, let alone use by unskilled people. The application of science is at best a prolonged social process. In many forms of society it is difficult or impossible. In primitive societies it is opposed by custom, often with a magical sanction. In the Middle Ages it was opposed both by the persecuting church and the monopolistic guilds.

Today it is very often opposed by monopoly capitalism. If I found out how to make diamonds tomorrow I should find it very hard to put my method into operation. If I wanted to make a fortune, my best plan would be to sell it to the diamond monopoly, who would promptly suppress it to save their mines from ruin. New methods are promptly applied if, and only if, they mean quick profits, and some capitalist can be persuaded that they do.

Another thing which my correspondents do not realize is that science is almost always quantitative. It depends on measuring, weighing, and counting. Now if I am asked a biological question which involves numbers, I can sometimes answer it at once, because I have been thinking in numbers about living things for thirty years. If you ask me how much vitamin B_1 would have to be added to our bread to suffice us for a year, I can make a rough guess at the answer. I can also estimate how much arsenic enemy planes would have to drop into the London reservoirs to poison us (and it is a very large amount), or whether there is a danger of suffocation in a particular shelter. I can do this because I have made thousands of calculations on such matters. But I am asked questions as to the possibility of keeping off bombs with wire nets, or stopping bombers by letting loose dust, wires, or chemicals which would cause "knocking" in their cylinders.

I could make the necessary calculations, or some of them, in a few hours or days, if I had the available time, though I should also waste a good deal of time in hunting up the necessary figures in libraries. Having made them I could be in a position to say either "This is worth following up", or "This would need millions of tons of material to stop one air raid". But a physicist, chemist, or engineer with the right qualifications could do the same sums roughly in a few minutes, and accurately in an hour. I know enough physics to understand the principles involved, but I haven't got the numbers at my fingertips.

Still less realistic are some of the people who write about their health. I would sooner take the opinion of a very second-rate doctor who had actually examined me than of the world's finest physician who had merely read a letter about my symptoms. For example headache may be due to eye strain, digestive troubles, kidney disease, or brain tumours, to take only a few examples. A doctor may give the wrong diagnosis, but I certainly can't put him right from a distance, and could not do so no matter what were my qualifications.

A few medical questions can be answered from a distance, largely because normal people's needs of food, oxygen, and so on, are much the same, and because a certain degree of overcrowding and dirt are bound to lead to some cases of disease. But in a grossly overcrowded shelter, though one can be sure that some people will fall ill, one cannot say which particular person will do so.

If children were taught science in relation to their daily lives and the work which they would probably do when grown up, my correspondents would realize these facts. But they learn their science from books, or at best from very artificial laboratory experiments. And it is no wonder that they attribute to me the qualities, not of a scientist, but of a magician.

Lord Birkenhead improves his Mind

I OPENED Lord Birkenhead's book *The World in 2030*,[1] with pleasant anticipations. "Here", I hoped, "I shall not be bored by a catalogue of possible improvements in engineering and medicine, but I shall be able to study the views of one of the acutest minds of our generation on the future of politics and law, of both of which professions he has been an ornament." I was early undeceived. In the preface he dashed my expectations to the ground by the statement that "of all branches of human knowledge, law and politics are . . . just the two that are least likely to sustain profound modification". His lordship may be correct, though I venture to disagree with him for the following reason. Until recently experts in two subjects only have enjoyed a pre-eminent advantage in the field of politics. These subjects were law and war. The power of the political lawyer has tended to formalize politics and to spread in political circles the tenet that:

> The law is the full embodiment
> Of everything that is excellent.

Today new types of expert are coming to the top in politics. For example, the President of the United States[2] is an engineer. The decline of the lawyer-politician is likely to have radical effects on law and politics alike.

I read further, and a strange feeling began to oppress me. Certain of the phrases seemed oddly familiar. Where had I seen them before? Finally I solved the mystery. They were my own. Here are some parallels between the two documents, of which B is the work under review, while H represents *Daedalus* or *Possible Worlds* by myself.

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[1] *The World in 2030*, by the late Earl of Birkenhead. Hodder & Stoughton 12s. 6d.

[2] At that time Herbert Hoover.

B. The Cambridge biologists bred and acclimatized a lichen which bound the shifting sands of the world's deserts, and made them fit for cultivation.	H. Ferguson . . . who in 1957 produced a lichen which had bound the drifting sand of the world's deserts. . . .
B. After the riots and civil disturbances caused, in 2010, by the introduction of state-supported ectogenesis in Nebraska. . . .	H. They certainly succeeded in producing the most violent opposition. . . . (There was even a rebellion in Nebraska.)
B. They are minute bodies, so small that, if a hen's egg were magnified to the size of the world, one of the genes in it would lie on a fair-sized writing-desk.	H. If we magnified a hen's egg to the size of the world . . . we could still get a gene into a room or even on to a small table.

The resemblance becomes more striking when I add that the first two pairs of excerpts are both from essays supposed to be written by undergraduates, the one in 2030, the other in 1978. Altogether I counted forty-four coincidences between the two documents, though I dare say the list is not complete.

Applying John Stuart Mill's method of agreement I formed the hypothesis that the documents B and H were causally connected, and noted that H was the earlier of the two. I have formed three provisional hypotheses to explain the facts: (*a*) Lord Birkenhead and I both had access to the same original document. This could perhaps be reconstructed, like Q, on which Saints Matthew and Luke (I make the comparison in all reverence) are said to have drawn. (*b*) We were both controlled, when in a state of trance, by the same discarnate intelligence. In my own case this is extremely plausible. I am in the habit of ingesting substances, such as calcium chloride, which temporarily affect the functions of my brain, and a "control" might well take advantage of such a condition. But it would be a tragedy if so brilliant a brain as Lord Birkenhead's were interfered with in any such manner. However, I am sure that his lordship has never even tasted calcium chloride. Perhaps he is more psychic than I. (*c*) Lord Birkenhead was guilty, I will not say of plagiarism, but of a certain lack of originality. I unhesitatingly reject this hypothesis, because it carries with it corollaries which I find unthinkable. Mr. G. K. Chesterton would have had some justification for writing the odious lampoon whose final line, "Chuck it, Smith", I blush to transcribe. And it would be possible to minimize the loss which the Unionist party has sustained through Lord Birkenhead's retirement from active politics. Even on this obviously ridiculous theory, there would, of course, be no infringement of copyright. The law is clear that when sufficient skill and labour are applied copyright is not infringed, and Lord Birkenhead's legal acumen would have gauged the necessary effort with the utmost nicety.

Adopting, as the least improbable, hypothesis (*b*), there would seem (as is so often the case with such psychic phenomena), to be an occasional failure in transmission. "Copper", we learn from B, "conducts electricity incomparably better than any other metal". In fact, aluminium is a better conductor, weight for weight. "If intra-molecular energy be tapped and utilized, the same state of affairs (unlimited supply of power) would arise." Intra-molecular energy is today tapped and utilized in almost all high explosives. From the pen of a director of Imperial Chemical Industries such statements would be surprising. From that of a medium they are not.

But it is in the sphere of law and history that the imperfections (inevitable in such supernormal manifestations) are most striking. "As equal citizens of the Empire, Saxon, Celt, Semite, Mohammedan, Hindu, Chinaman, and Maori share similar rights and are subject to equal responsibilities." The control may well have believed this. A former Lord Chancellor and Secretary of State for India might perhaps have been cognisant of the existence, in that portion of the empire, of two highly complicated systems of civil law, defining the rights and duties of Hindus and Mussulmans as such. "The Roman Empire, however, stood and fell with Rome. The city *was the only heart of the Empire." It is unfortunate that the control had not learnt the mnemonic:*

The Emperor Arcadius
Lived outside the four-mile radius,
Which made it very laborious
To go and dine with the Emperor Honorius.

If so, he, she, or it would have remembered that the Eastern portion of the Roman Empire, of which Constantinople formed the heart, was separated from the Western before the fall of Rome, and survived that fall by nearly a thousand years.

Between the psychically inspired passages there are portions —in one case of no less than twenty-three pages—which appear to be original. There is a eulogy of the tank, some mild anti-French propaganda, one quite bright remark about the League of Nations, some anti-feminism, and just at the end, eight quite amusing pages on the application of psychology to law and politics, which go some way to belie the statement which I have quoted from the introduction. There are, it must be admitted, some curious gaps. One may not like Bolshevism or Fascism, but a prophet who ignores both in his consideration of world politics might be thought, by a captious critic, to be limiting his outlook unduly.

Whether these original passages are worth twelve shillings and sixpence I will not attempt to decide. But if readers of the book should answer the question in the negative, one consolation will remain with them—Lord Birkenhead has made the acquaintance, whether from the document Q or from a discarnate intelligence, with some popular science. And no doubt this has improved his mind.

NOTE

This review was published in the *Week-End Review* in 1930, and has also been reprinted in *The Week-End Calendar* (Geoffrey Bles). I reprint it here because it has some historical interest, and because the incident was one of many which woke me up to the remarkable fall in the moral standards of the British ruling class which has occurred in the last generation. The law of libel prevents me from mentioning most of the others. Given Lord Birkenhead's record, I should not have been surprised at his attempting to make a fortune "by some great base mean", but I was surprised that a former Lord Chancellor and a Lord of Appeal should make a few hundred pounds by petty pilfering of another man's literary property. I should not be so surprised now. But since 1930 I have become a Marxist, and I must thank Lord Birkenhead and Adolf Hitler, among others, for making me one.

A Banned Broadcast (1934)

DEAN INGE, Sir Norman Angell and Lord Beaverbrook have told you some of the causes of war, but not all. Dean Inge dealt mostly with psychological causes; the other two, who didn't quite agree, with political causes. I am going to deal with the technical and economic side. It may be true that hate and fear are the root causes of war, but we shan't get rid of them in our time. If I were asked about the causes of fires in houses, I shouldn't tell you that the main cause was oxygen in the air, because that is outside our control. I should talk about the use of too much wood in building, about carelessness with matches and cigarettes, and lastly about our system of insurance, which makes fires a source of profits for some people.

The first thing to get hold of is that the British Commonwealth is extremely powerful in attack, but is also extremely vulnerable. We could attack any nation with a sea coast. But we are vulnerable to blockade or air raids. Whereas the Soviet Union, for example, is not so strong in attack, but probably stronger in defence. Now this makes for war for two reasons. It makes other nations fear us, and therefore, as Dean Inge said, hate us. And it gives their politicians the hope of attacking us successfully. So if we can make ourselves less vulnerable, and at the same time less alarming to others, we shall be helping the cause of peace.

During the last war we were very nearly beaten by the German submarine blockade, and Cabinet Ministers tell us that in the next war the enemy aircraft may drop a greater weight of bombs on London in a single night than they did in the whole of the Great War. What have we got to protect ourselves from these dangers? Very little.

We have one of the world's two largest navies, but the naval experts tell us that without many more cruisers they could not protect our seaborne commerce. We have a small though efficient air force, but the air experts tell us that a far bigger force could not guarantee us against raids, but only bring down some of the raiders, and bomb the enemy in reprisal. In a future war our shipping may be attacked by submarines, cruisers, or aeroplanes. We could probably overcome the danger if we had time, as we did that of the German submarines. But shall we be given time?

Our reserves of food in this country are very small. Sometimes we have only three months' supply of wheat. If we had three years' supply of wheat in national granaries we could laugh at the threat of starvation, and no other Power would be led into war by the hope of starving us out. The cost of such storage and purchase has been worked out. It would probably run to over £200,000,000, but it would cost much less than our navy, and would not frighten anyone. I need hardly add that the wheat is waiting to be bought, and the workers who could make such granaries are waiting to be employed.

Air raiders might attack us with explosives or gas. Besides aeroplanes, balloon barrages, and anti-aircraft guns, there are three other lines of defence. First, gas masks. Fairly good gas masks could be made for about half a crown apiece. But they could not easily be kept in good repair, it would be hard to teach people to use them, and they would not protect the skin against blistering vapours. Again, every house in our large towns could be given a gas-proof room. This would cost a lot more, and would be no protection against explosives. Finally, all the thickly populated parts of our large towns could be equipped with bomb-proof and gas-proof underground shelters. This would cost a great deal, but it would be of immense value. In fact, if such shelters existed, it is likely that they would never be used, because an enemy would probably not violate the laws of war by bombing civilians unless he thought he could force a decision by so doing, as the Germans hoped to win the war by sinking neutral ships.

If we had protection of this kind, we could afford to reduce our expenditure on ships and aeroplanes, and people in other countries would be less afraid of us. But as you know, our Governments have done nothing along these lines, though the need for such action has been obvious since 1920. I am not trying to make party capital. There is nothing to choose between the Conservative and Labour parties in this respect.

Now why is passive defence completely neglected? There are four reasons. Our politicians were brought up in the days of horse cabs, and won't think in terms of modern transport. The fighting services have that incurable prejudice in favour of attack which sent infantrymen like me against uncut barbed wire, and refused to give us machine guns for defence. The storage of food would involve at least a partial nationalization of the food trades, which is all wrong, because it is Socialism. And above all we have a heavy and continual propaganda from interested parties in favour of increaased armaments. I only wish the farmers and the engineers who would have to excavate dugouts were as enterprising as the armament firms, and would subsidize propaganda for the storage of wheat and the making of bomb-proof shelters!

I notice that Dean Inge has no use for the idea that armament manufacturers ever frighten us to make us buy their wares. They would be very remarkable people if they didn't. I can't open a newspaper without finding an advertisement intended to frighten me into buying tooth-paste or pills. The armament dealers are a little more subtle in their methods, but that is all. After all, common sense tells you that when you find an evil you should inquire who is making money out of it, and then you won't be far off its cause. If you want to catch fire-raisers you find out who is making money out of fires. If you want to catch war-raisers find out who is making money out of wars and rumours of wars.

Now don't turn off your receiver in disgust because this doctrine is historical materialism or Marxist propaganda! It is Marxism. But it is also common sense, and it is also good Christianity. It wasn't Karl Marx who said, "Where your treasure is, there will your heart be also". I think that if Dean Inge had had that text in mind he wouldn't have been quite so certain that armament shareholders would never obstruct disarmament. Actually we know that men employed by armament firms do so. Our present naval competition with the

United States is partly due to the efforts of a gentleman who was paid by an American armament firm to interfere with the Anglo-American conversations at Geneva.

The men who framed the Covenant of the League of Nations thought differently from the Dean. Clause 4 of Article 5 begins, "The members of the League agree that the manufacture by private enterprise of munitions and implements of war is open to grave objections". When Mr. Lloyd George agreed to that clause on our behalf, he had learned a great deal about armament firms while he was Minister of Munitions. That clause, which is a Socialistic clause, was drawn up by such eminent anti-Socialists as Viscount Cecil and General Smuts. They realized that at least some kinds of private enterprise are among the causes of war.

Of course, every shareholder in an armament factory does not go about clamouring for war. But he or she realizes that if the promises to disarm made in the Covenant on behalf of the nations were carried out, it would mean a loss of income, and that a war, especially a nice little war on the other side of the world, would mean a financial gain. Let us put the thing as gently as we can. You can't expect those people to be quite as keen on peace as the rest of us, and when peace and war are in the balance that little lack of keenness may turn the scale.

Let us see what else besides the armament firms has an interest in war. Perhaps we haven't been quite fair to them. After all, an army needs boots and breeches as well as guns. It gets better food than the civilian population. It needs transport. And, above all, it does not compete with civilians in the labour market. If you talk during a period of great depression, such as 1931, with a man who is engaged in financing international trade, he will often say something of this kind: "I hate to say it, but you know a war would set the wheels of business going again. Of course, I don't mean a war in which we are involved. But look how well the neutrals did in the Great War!"

If Japan and the Soviet Union went to war tomorrow, not only would they want to buy munitions from us, but raw materials of all kinds. The Japanese would want their ships for transport, and British tramp steamers would take their places. Their factories would be too busy making army uniforms and explosives to compete with Lancashire. The immediate effect of such a war would probably be a fall in British unemployment. No wonder, then, that some British business men would not exert themselves to stop such a war; even if they would do their best to prevent this country from being drawn into it. In the same way, many Japanese would benefit financially from a war in Europe.

That is rather a terrible situation. It means that wherever you have unemployed labour and unemployed capital you have a cause of war. When markets are expanding, as they were through most of the nineteenth century, this cause is absent. As long as we could sell cloth and rails to the Russians and the Japanese it was in the interests of almost every Englishman that they should keep the peace. It is not so any more. And I need not tell you that wars have a way of spreading. If the Soviet Union were at war with Japan, a European power might be tempted to attack her, and we should find it very hard to keep out.

Lord Beaverbrook thinks we could keep out by refusing to commit ourselves to aid any other nation. Well, America had no commitments, and President Wilson tried to keep out of the Great War, but he failed. If submarines were being used against commerce in a Franco-German war, does Lord Beaverbrook honestly believe that no British ships would be sunk? On the contrary, we have a far larger mercantile marine than the Americans had in 1917, and should far more certainly be involved.

When unemployment rises beyond a certain point things get still worse. Germany had five or six million unemployed in the winter of 1932. They were desperate, and no one can wonder that many of them supported Hitler when he promised them work, even though his policy, which involves the absorption of the German-speaking people of Austria, Czecho-Slovakia, Poland, and Denmark, can only be achieved by war. I sincerely hope that, in spite of this declared policy, Germany may not go to war, but there is no question that the danger of it is far greater as a result of Hitler's advent. By the way, Lord Beaverbrook forgot to mention that the Nazi programme includes the return of the former German colonies. It is a pity that he did not tell us how he would answer such a demand were Germany supreme on the continent of Europe, with a very large air force within striking distance of London.

As long, then, as we have massive unemployment, there is a very good reason for war. Every unemployed man or woman is a cause of war. I see no prospect of abolishing unemployment under our present economic system. That is why I am a Socialist, and it is one reason why more and more lovers of peace are becoming Socialists.

I notice that Dean Inge made the really amazing statement that one cause of war was pressure of population on the means of subsistence. Actually the opposite is true. The world contains enough means of subsistence for a much larger population. Our Government is busy trying, by quotas and tariffs, to keep various means of subsistence out of the country. No wonder with such an economic theory he was unable to make any very constructive suggestions.

I want to deal with one more cause of war. Lovers of peace are hopelessly divided in their policies. If peace is as important as I believe, we ought always to ask ourselves, "Does a given policy make for peace or war?" and act accordingly. Let me give you two examples:

In 1921 the Greek Government rejected the British, French, and Italian proposals for a peace with Turkey, and launched an offensive into Asia Minor. In 1922 the Greek army was defeated. There was a revolution, and the commander-in-chief, the Prime Minister, and four other ministers were executed. This was one of the most impressive gestures for peace made in our time.

I think it will be many years before another Greek Government enters into a war. What happened next? The British Government protested strongly, and withdrew its Minister from Athens. They had not withdrawn him while tens of thousands of ordinary Greeks and Turks were being slaughtered, but five ministers and a general were another matter. They showed that they preferred the safety of Cabinet Ministers to the safety of peace. Thälmann, the German Communist leader, is in prison today. It is reported that he is shortly to be tried, and may be sentenced to death. Among other things, he is accused of addressing a meeting in Paris, where he demanded international action for peace by the working class. Thälmann is standing for peace against the warlike policy of Hitler. It will be interesting to watch the reaction of British opinion if he is executed. Dean Inge says that friends of peace may pray to be delivered from such allies. Yet in war we are not so particular about our allies.

Two more examples:

The University of Oxford conferred an honorary degree on Sir Basil Zaharoff, the eminent armament manufacturer. The Vice-Chancellor of Leeds University has just censured Mr. Dickinson, one of its lecturers, for making a very forcible speech in favour of peace. I wonder if our Universities are doing all they can to prevent the next war.

To conclude, if we really want peace, we must examine all the causes of war, economic and technical, as well as psychological and political. We must be prepared to associate with all sorts of people, from Bishops to Bolsheviks, who share our aims. We must try to convert others as I have tried to convert you.

NOTE

I reprint this broadcast because it is of some slight historical interest. I was asked to take part in a B.B.C. discussion in the autumn of 1934. Dean Inge, Sir Norman Angell, and Lord Beaverbrook had already spoken, the latter in favour of isolation. The B.B.C. refused to permit this broadcast here reprinted. I offered to tone down some of the Socialism and to cut out the controversial matter at the end. They still refused. I did not feel justified in cutting out my pleas for food storage and A.R.P., so the broadcast was not given. It was, however, published in the *Daily Herald* on November 3, 1934.

I have of course reprinted this article without alteration, though I have changed my opinion since, and would have put several things differently had I then held my present views. I should have emphasized more clearly the distinction between the private and public manufacture of armaments. Above all I did not foresee that British Governments would violate international law in favour first of Mussolini, and then of Hitler, as they did from 1935 to 1938. Hitler was supported by armament manufacturers in various countries. Herr Stinnes, who financed him, escaped, but was handed over to the Gestapo by the Vichy Government. This is the only action of that government with which I have some sympathy. Lord Riverdale, of Sheffield, was one of the British armament manufacturers who spoke in favour of German rearmament. Unlike Herr Stinnes, he has found the war which resulted from it quite profitable.

I should like particularly to point out that in 1934 (and indeed earlier) I was demanding respirators and bomb-proof shelters. In 1938 I was one of the founders of the National A.R.P. Coordinating Committee, of which I am Chairman. It continued these demands, in great detail, and of course in a more up-to-date manner. Thus in November 1939 we saw that underground shelters for all were impracticable, and urged the building of reinforced surface shelters. These were begun in the summer of 1941, after many lives had been lost in brick shelters, and many million pounds wasted on them. In that year the *Daily Herald* stated that the A.R.P. Coordinating Committee was a Communist organization. Actually it includes members of several political parties and of none. And in 1934 I had no connection with the Communist Party, and became associated with it mainly because of its full awareness of the dangers of Nazi and Fascist aggression. It also led the way in demanding adequate A.R.P.

It would be interesting, by the way, to know just who was responsible for suppressing this broadcast, whether he or she was the same person who ordered birthday greetings to be sent to the King of Italy in 1941, and whether he or she is still directing the policy of the B.B.C.

I was a Biometrician

IN November 1918 the staff of the German university of Strassburg were forced to evacuate at a few hours' notice, and although the French university of Strasbourg proved a worthy successor, the expulsion of the German professors who were unable, so it was said, to remove their apparatus and books, was regarded as a crime against learning. Perhaps we were over-sensitive in those days. Thousands of German, Austrian, and Czech men and women of learning have been expelled since 1933. Since 1936 their Spanish colleagues have undergone a similar fate. Some of the Chinese universities have been deliberately bombed. Others carry on a precarious existence under the Japanese, or in Yunnan and Szechuan. The university of Warsaw is being destroyed as I write.[1]

Among the latest additions to the list of refugee universities is that of London. A skeleton staff has been evacuated from some of the teaching departments to Exeter, Bangor, Cambridge, and other towns. Except in the Imperial College of Science, and a few departments in other colleges which have defied orders to evacuate, research has ceased. Libraries are closed.

In the case of the non-biological sciences the temporary cessation of research is often not very serious. In my own it would be fatal. Some of my pedigree stocks have been preserved so far. Others have found, or may later find, refuge elsewhere. Other animals of known pedigree have had to be destroyed, and many years' work will be required to build up similar stocks again. The enforced slowing down of my work at least gives me an opportunity to review it. I came to London in 1933 as part-time professor of Genetics, and since 1937 have been Weldon Professor of Biometry, a science which is defined as the application of higher mathematics to biological problems. The success, such as it has been, of my department, is largely due to two men, Adolf Hitler and the late John D.

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[1] September 1939.

Rockefeller. The former provided me with personnel, the latter with money to pay them.

The department concerned itself with the details of inheritance in flies, beetles, mice, rats, and men, and also with the study of natural populations of these animals. As an applied mathematician I devised statistical methods, and applied them to the work of my junior colleagues, to that published by others, and to a little of my own. My chair was endowed by the widow of the late Professor Weldon, a zoologist with a bent for mathematics, who had worked in conjunction with that great man, Karl Pearson.

Karl Pearson saw that mathematics could be applied to biology. However his philosophy, which resembled that of Mach, but was more consistent, lead him astray to some extent. He refused to look below the surface of phenomena because he thought there was nothing to look for. "This honest and conscientious enemy of materialism", as Lenin described him (and Lenin rarely erred on the side of politeness to his opponents), collected data on inheritance in men, horses, and other animals, and attempted to describe the phenomena of inheritance in purely mathematical terms. He and Weldon were violent opponents of Bateson, Punnett, and other workers who followed up the clue which Mendel had discovered in peas. Thirty-five years ago it seemed impossible that both parties should be right. But they were. Bateson's theories, though fundamentally correct, were far too simple. Pearson's elaborate mathematical apparatus, when applied from his essentially positivistic point of view, led to meagre biological results. But once the more materialistic theory of the gene, which Morgan built up on the basis of Bateson and Mendel's work, had developed beyond its early stage, Pearson's mathematical methods proved indispensable.

I have been applying and developing them. The last paper which appeared from my department before the war, dealt with the following problem. Haemophilia, a condition in which the blood will not clot, occurs in men only, but is handed down through women. A woman transmitter hands it down to about half her sons. What fraction of her daughters inherit her curse? To take a concrete example, Queen Victoria had one haemophilic son, Prince Leopold, out of four; and two of her five daughters, namely Princess Alice of Hesse and Princess Beatrice of Battenberg, had haemophilic sons. But we cannot say that only two out of five daughters were transmitters. The other three daughters had seven sons between them. If they had had more, one of them might have borne a haemophilic son. In a group of such cases we can make the necessary allowances. And when we do we find that about half the daughters are transmitters. The calculation, however, involves quite difficult mathematical and, above all, logical thinking.

My colleague Dr. Philip has been breeding wild mice. This involved a study of their psychology, for they insist on being let alone before they will breed. Mice seem to act on the Nazi philosophy. In one Scottish mine there were both white-bellied and grey-bellied mice. They will hybridize in captivity. But there were no hybrids in nature. On the other hand a population of beetles with four colour varieties were found to have bred at random as regards colour. There had been no tendency of like to mate with like. My colleagues Gordon, Christie, Spurway, Street, and Rendel worked with a wild species of flies all of whose members look very similar. But by inbreeding them they showed that many of them carried recessive genes which made no difference to their appearance, but showed up in their descendants as a result of inbreeding. A number of true breeding races differing from the type were established. Some of these were freaks, but others possessed characters normally found in other species. Finally my colleague Grüneberg studied a variety of congenital diseases, such as cataract, deafness, and anaemia, in mice and rats.

Apart from its bearing on evolution, this work was mainly valuable in providing a background against which to study human problems. There is a congenital element in a great deal of human disease, yet a hundred people have worked on infectious diseases of animals for every one who has studied their congenital maladies. So much nonsense has been talked about race-crossing, racial purity, and similar topics in man that we are apt to forget that there are very real questions to be answered in this field. For example there is certainly a Jewish problem, or rather a number of Jewish problems. Perhaps the central biological one is as follows. "Do the Jews taken as a whole, differ as regards innate physical characters from their neighbours, as for example the Red Indians of North America differ from the whites, negroes, Chinese, and hybrids?" Only if the answer to this question were affirmative would there be any point in conducting research on the much more difficult problem as to whether the Jews differ from their neighbours in a similar way as regards innate psychological characters.

My department has attempted to answer such questions as these in the case of animals where no political, religious, or social theories were likely to bias the investigators. I believe that such work, if it does nothing more, helps us in two ways with the human problem. It gives us a background, as the study of animal anatomy or animal behaviour gives us a background against which to study human anatomy and behaviour. And it enables us to test out methods on relatively favourable material.

In the same way our work on congenital abnormalities in animals, if it does not answer the problems of human eugenics, at least suggests the methods by which they may be answered. Above all it warns us that the answer may not be simple. Some congenital abnormalities in animals can be got rid of by "sterilizing the unfit", others can be reduced in frequency by preventing inbreeding. With others again, neither of these methods is very effective.

All this work is what some people call pure science, but I prefer to call it long-term science, because its results, though ultimately of great importance, are not immediately applicable. The action of the authorities of London University has shown that they do not regard such work as particularly important.[1] If, as some people believe, though I do not, our civilization is about to collapse, they are doubtless correct. Horse racing is not, like scientific research, a prerogative of civilized peoples, and some will think that so long as pedigree race-horses continue to eat food which might be otherwise used, a war to save civilization might respect humbler creatures which serve science. Clearly this is the opinion of a minority.

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[1] It is only fair to say that at a later period in the war they were much more helpful. Some of them read this article.

I must however confess that among the reasons which confirmed me in my belief that in the recent conflict the defence of Madrid was the defence of civilization were the activities of Professors de Zulueta and Galan. At least up to January 1938 they continued to carry on research on heredity in beetles and cucumbers within less than two miles of the trenches, and under occasional bombing and shell fire. Madrid fell, perhaps just because its people thought that kind of thing worth while, and did not sacrifice all other considerations to the successful prosecution of the war. Whether or not the policy of the Spanish Government was right, London is showing somewhat less concern for scientific research than did Madrid two years ago.

NOTE

I have managed to keep my department going and most of its members have collaborated as a team in the work described in the next articles. I have deleted a passage which was justified at the time, and was violently criticized. However it played its part in causing the university authorities to adopt a much more enlightened policy. In fact since 1940 they have served the cause of science and learning well.

My War Job

PART I

IN the course of the war millions of people are put in situations which endanger their life, health, or efficiency, quite apart from enemy action. We have only to think of men in overheated tanks, women exposed to T.N.T. poisoning, children in overcrowded shelters. A great deal can generally be done to protect them, but very often research is needed before this is possible. I have been engaged in work of this kind throughout the war, but much of it is quite rightly secret. However the Admiralty has allowed me to publish accounts of one piece of work in *Nature* and the *Journal of Hygiene*, so I am free to write of it here.

In 1939, at the request of the Amalgamated Engineering Union, I had done some work bearing on escape from submarines, and the Admiralty asked me to continue it, while Messrs. Siebe Gorman & Co. who make the Davis submarine escape apparatus, put their works at my disposal.

If a submarine is lying on the bottom, say under 100 feet of water, and cannot rise, the crew can get out by opening a hatch. But they cannot do this until the air pressure inside is equal to the water pressure outside. At a depth of 100 feet the air pressure must be 4 atmospheres, that is to say a cubic foot of air must be squeezed into ¼ of a cubic foot. At 300 feet the pressure must be 10 atmospheres, or 150 pounds per square inch, and so on; an extra atmosphere for every 33 feet. The pressure may be raised either by flooding a whole compartment of a submarine, or by flooding a small escape chamber which normally only holds two men. So my first task was to find out some more about life in compressed air. We used a small tank much like a boiler, 8 feet long, but only 4 feet high, with small windows of thick glass, and an airtight door.

My colleague Dr. Case and I used eighteen volunteers as "rabbits", and one of us was always compressed with the "rabbit". Our "rabbits" included such distinguished men as Dr. Negrin, the former Spanish Prime Minister, and Col. Kahle, who commanded the International Brigades. Two of the "rabbits" were women. One of the men was severely injured, and many lost consciousness, but I never had any difficulty in getting volunteers.

How quickly can a man be compressed with safety? This may be a matter of life and death. We do not feel the extra pressure, any more than we feel that of the normal air, provided it is evenly distributed. But everyone feels it on the ear drums, because the outer side of the drum is exposed to air, while the inner side communicates with the throat by the Eustachian tube, which is generally kept shut. If this tube is not opened, there is great pain, and an ear drum may burst, causing deafness till it heals again. Experienced divers can hold it open. I can myself. Most people can open it by holding the nose and blowing, but this is often supposed to be rather difficult to learn. I found that about four people out of five need no training.

Certain people thought this was only true for biologists and medical students, so I got four men from the British Battalion which had fought in Spain, none of whom had ever been in compressed air, and compressed each of them to 10 atmospheres in 5 minutes, a speed which until recently was thought dangerous even for experienced divers. The rate of increase of pressure on the ears is the same as one would get in a plane nose-diving at 600 miles per hour. I admit that one of the four lost consciousness for a moment, but none of them asked me to stop the compression.

You feel pretty queer at 10 atmospheres. The air is so thick that you feel quite a resistance when you move your hand, and your voice sounds very odd, as if you were trying to imitate a Yankee twang, and overdoing it very badly. But after a minute or two you also feel changes in your mind, somewhat, but not exactly, as if you were drunk. Americans and Irishmen generally get very excited and may be quarrelsome. So do some Englishmen. Others become miserable, and say they are dying. Dr. Negrin was one of the few who preserved a complete outward calm, though his written notes show that he was feeling rather odd. In this condition most people can still do fairly well on simple tests of manual skill, however (except for one woman) they cannot do arithmetic or think of several things at once—for example testing a "rabbit", taking notes, and collecting a sample of air. But they can carry out a drill.

This condition, as was first shown by Commander Behnke, of the U.S. Naval Medical Corps, is due to the fact that nitrogen is a poison if you have enough of it. Four-fifths of air consists of nitrogen, which is generally supposed to be inert. But when you increase the amount in a lungful five times or more, it becomes an intoxicant—a simple example of the change of quantity into quality, on which Marx and Engels laid such stress. It is easy to prove that the nitrogen is responsible, by breathing, not air, but a mixture in which hydrogen or helium is substituted for nitrogen. One recovers in two or three minutes.

So far we had not had a very difficult job, but when we got onto the next problem, "What happens if the air is foul?", we were not so comfortable. I shall describe these experiments in the next article.

My War Job

PART II

IN my last article I described some work on which I have been engaged to make escape from submarines easier. Since, before the crew can open a hatch, the air pressure inside must equal the water pressure outside, we had to investigate life in compressed air. Now the air in a submarine which has been under water for some time is fairly foul. The men have used up some of the oxygen, and produced some carbon dioxide.

The effect of a gas mixture on human beings does not depend on its percentage composition, but on the amount of gas in a given volume. So even if the oxygen has been a great deal reduced, they will get all they need under pressure. Thus if half the oxygen had been used up some of the crew would probably be unconscious, and all would be weak and stupid. But if this air were compressed into half its volume, they would get as much oxygen in a breath as in ordinary air, and recover completely. Unfortunately the same holds for carbon dioxide. If there is 2 per cent of this gas in air at atmospheric pressure, you may not notice it at rest, though you are rather short of breath when working. But if you squeeze this air into a third of its volume, you find yourself panting for dear life, as if you were breathing 6 per cent at the normal pressure.

Our main experiments were on the effect of carbon dioxide at a pressure of 10 atmospheres, corresponding to 300 feet of sea water. We worked in a little tank 4 feet high and 8 feet long. First my colleague Dr. Case and I found out how much was needed to make ourselves unconscious. Then we started to work on others.

One of us would sit, breathing through a canister containing a mixture of lime and soda to absorb the carbon dioxide, whilst our victim breathed it directly until he or she lost consciousness. The victims were given a simple test of manual skill to see how badly they were affected before they passed out. They were almost all tough enough to go on with their job, or try to, till they stopped with their mouths open (for they were panting hard) and a glazed look in their eyes. They did not answer when spoken to, or even poked. Then some of the air was let out, and they recovered consciousness.

At least that was what was supposed to happen. But the compressed air by itself made me feel so queer that I sometimes forgot to breathe through the canister again after speaking to the victim, and I passed out too. In this case someone watching at the window would lower the pressure. And occasionally the victim vomited or made trouble.

We found that people varied a great deal in what they could take. I am no better than the average of our volunteers, though I dare say I am better than the average man in the street would be. Our two women volunteers were both better than most of the men. The one man whom we failed to knock out with a very high dose is a little International Brigader called Jacobs. He was the only Jew on whom we experimented, but he continued writing quite calmly when Nordic blonds had taken the count long ago. As a result of our tests we reached a definite conclusion as to the amount of carbon dioxide in which men could not merely keep conscious, but work.

We also had to investigate the effects of cold. Dr. Case or I lay, dressed in a shirt and trousers, in a bath of water and broken ice, till we began to shiver. This takes about 20 minutes in my case, but a shorter time for most Englishmen. I dare say many Russians would take longer. Then the air pressure was raised, and whoever was in the bath was given problems in mental arithmetic or made to recite verse; for we were shivering too badly to do anything much with our hands. Sometimes some carbon dioxide was added to the air as an extra. We found that the cold only made the symptoms very slightly worse.

When the war is over it will be possible to describe further experiments; but at present I cannot even answer letters regarding the question of escape from submarines, much less write a full account of it.

But I can draw some morals. This work should have been done in peace time, in a more leisurely and systematic way. So should a vast amount of other work of the same kind. Whenever men and women are to be put under abnormal conditions, the effects should be tested before some of them are killed or maimed, not after. No-one dreams of using a ship, an aeroplane, or a car, till its various parts have been tested. But we do not apply the same notion to human beings. This is partly because we do not think of them materialistically, as we think of machines, partly because the people at risk are often "only" workers, anthracite miners, stokers, or cotton blow-room operatives, for example.

The necessary experiments are not quite safe or very comfortable. Nor are dirt-track racing, mountaineering, or many other things which men do for pleasure. I have no doubt volunteers could be found. But nothing will be done without pressure from the Labour Movement. When the T.U.C. appointed Sir Thomas Legge, our greatest expert on industrial diseases, as its medical adviser in 1929, it did a very wise thing. Unfortunately he died in 1932. Perhaps after the war it may itself start, or force the Government to start, experimental work on industrial dangers, as straightforward as that which I have described.

What I am Fighting For (1942)

UNFORTUNATELY I am not fighting in the strict sense of the word. But my job is more like fighting than those of most men of 49. I have to test certain apparatus used by one of the fighting forces. In doing so I have been injured and might have been killed. And as far as I am concerned this war began in 1936. I spent some time in the front line during the Spanish Republic's heroic fight against Fascist aggression.

I want to see Socialism in my time in England, and would be quite ready to fight for it if a minority attempted to prevent its coming when a majority desired it. But that is not what I am fighting for today; or at most that is only one of the things, for a Nazi victory would make many other good things besides Socialism impossible.

One of Hitler's most striking achievements is the number of nations, and the number of sections of opinion, that he has contrived to unite against him. Primarily I am fighting for something on which a Chinese peasant and an English factory worker, an American millionaire and a Soviet Commissar, a monsignor and a rabbi, would agree upon, the belief that every human being has some claim to consideration. This is what Hitler denies. Apart from members of the German Race, and (for the moment), their allies, other human beings are mere instruments, to be killed or enslaved as suits his purpose. Today a Pole or Ukrainian under the Nazis has rather less rights than an animal in England, which is at least protected from some forms of cruelty.

Of course I am fighting for a great deal more than this. I am fighting for all the principles of the Atlantic Charter, though I wish that document went a lot further. However, if it is implemented, it will mean a lot. For example freedom for India, and the impossibility of cornering raw materials, whether by rubber tycoons in London or their opposite numbers on Wall Street.

As an Englishman and a Communist I have two special interests. I want to see my country free to contribute to civilization as it has done in the past. That does not mean that I would have taken part in the wars against revolutionary America or France, or against the Boers. I don't believe in the slogan, "My country, right or wrong". But defeat in this war would mean the end of everything that has made England more worth while to the world than Bulgaria or Afghanistan.

My feelings about the Soviet Union are not very dissimilar. This Union has shown that Socialism can work, even if it is started in a very illiterate and poorly developed country. The heroic resistance of the Soviet Peoples has shown to the world what I knew before, that by and large, they are pretty satisfied with their way of life, and certainly not longing for deliverance from it. I want to see Socialism everywhere, though I don't suppose Socialism in Britain would be very much more like Socialism in Russia than the Church of England is like the Russian Orthodox Church. Hence I am extremely glad to be fighting for the land of Socialism. Incidentally as a scientist I am glad to be fighting for a country which is already leading the world in some branches of science, and is likely to do so in many more.

I am also proud to be fighting, not only to liberate the peoples of Europe, but those of China, which has the world's greatest record of continuous culture, and for the freedom of the United States, the first parliamentary democracy. And I know enough decent Germans, Italians, and Japanese, to be glad that I am fighting for their freedom too.

Though I hope we are going to concentrate on beating Hitler first, the defeat of Japan may be just as important for the world in the long run. In each case we shall have failed unless we take away all possessions and power from the class responsible for aggression—in Germany the big industrialists as well as the Nazi and army leaders,—in Japan the officer class. You have a magnificent museum of oriental art in Boston. When I next go there I want to see the "seven sacred treasures" of Shintoism on exhibit, for that cult—you can hardly call it a religion—is a danger to the world.

Finally I am fighting for my life. I know enough about what has happened to professors in Poland and Czechoslovakia to guess my fate if Hitler won, whether my country was occupied by the Nazis or only ruled by Mosley and Ramsay. If I have to die in the next year I don't want to be beaten to death or executed. I would rather die fighting.

• 2 •

THE UNIVERSE

What is Matter?

MATERIALISM means the belief that matter really exists, whether anyone is aware of it or not, and that it was there before any mind perceived it. Idealism is the doctrine that mind was there first, and that a thing unperceived does not exist. If there is anything in an empty room, it is only because God sees it. There are various intermediate theories.

I am not going to argue the case for or against materialism, but to point out what is meant by the word matter. It is derived from the Latin *materia*, which originally meant wood, but later any stuff of which other things were made. But the Romans meant something very different from the modern idea of matter, by this word. They took over a Greek doctrine that things were made of earth, water, air, and fire, mixed in various proportions, the densest substances containing most of the "element" earth, and so on. We look at things quite differently today.

The same substance, say mercury, can exist in states corresponding to the four "elements". When very cold, it is a solid metal rather like lead. At ordinary temperatures it is a liquid. At still higher temperatures it boils away as a gas or vapour. And if we excite this vapour with an electric discharge it becomes luminous or "fiery". So it is more appropriate to regard the "elements" of the ancients as qualities rather than substances, and to say that mercury may be solid, liquid, or gaseous, and that the gas may also be luminous. Of course many compounds and mixtures, for example wood or leather, can only exist as solids, and are destroyed if we try to melt them. Others such as fat, can exist as solids or liquids, but not as gases, except at very low pressures.

All this seems simple to us, but it took a long time to get it clear. Thus three centuries ago "spirit" meant anything which left a solid or liquid in an invisible form. It might be the human spirit which was supposed to leave the body at death, "spirits of wine" which left wine when it was heated, and condensed as brandy, or "spirits of salts", that is to say hydrochloric acid, which left common salt when it was heated with sulphuric acid. Our ordinary ideas of today only became possible when it was realized that there were a great many different sorts of gas and vapour, and that they could all be condensed to liquids or solids, so that they were just as material as anything else.

And this, in turn, only became possible when airtight tubes, and particularly glass tubes, were available. For the progress of science, glass has been the most important of all materials. It made the telescope and microscope possible. It made it possible to watch the progress of chemical reactions, even of inflammable substances or those with poisonous vapours. Almost all the reactions which take place in metal containers in chemical factories were first carried out in glass vessels. If there were no such thing as glass, I am quite sure that our scientific theories would be very different. I do not mean that there are different kinds of truth; but we should have discovered truths in such a different order that the world would seem very different to us. We should probably have quartz lenses, for example, but they would be so expensive that microscopy would still be in its infancy.

The knowledge that gases were a kind of matter convertible into solids and liquids gave the clue to many properties of matter. For example when gases could be weighed it was shown that chemical or biological actions produce no measurable change in the weight of the matter taking part in them. That is to say matter, measured by weight, is practically indestructible. But only one hundred and fifty years ago people were thinking very differently. Gases were described as fixed air, dephlogisticated air, and so on, being thought to be different forms of the same substance, air. Now we say that they. are gaseous hydrogen, gaseous oxygen, and so on. We have changed round the substantive and the adjective.

In the same way two hundred years ago men spoke of electrified substances, but now we think electricity is itself a substance, and we measure its amount in coulombs. Similarly we think of energy as a substance. This has become particularly easy since energy became a commodity bought and sold in therms, kilowatt-hours, and other units. It is easy to think of matter in this way, as composed of various substances which undergo transformations. And this is how we think for many purposes in scientific work. However this kind of thinking leads in the long run to mechanism, that is to say the view that men are machines and the universe is a machine.

But many facts cannot be explained on this view, and few people are willing to believe that they are machines. So this view soon generates its opposite, that men and the universe are machines whose working is constantly interfered with by miraculous or at any rate immaterial forces. This means giving up the scientific method just where it becomes most important, namely when it is applied to human beings and human societies. And it must be remembered that biologists have searched quite vainly for any evidence of immaterial forces such as a "life-force" acting on ordinary matter in living things.

So scientists are more and more adopting the view of Marx and Engels that nature consists of processes or events rather than things, and that though hydrogen, oxygen, iron, and so on, are much more stable than the so-called elements of the Greeks and Romans, they are not the eternal bricks of the universe. This was made fairly certain by the work of Rutherford and his pupils. They showed that though atomic nuclei and electrons were mostly very stable at ordinary temperatures, yet some atoms broke up, without external shocks, and all were liable to change at very high temperatures. In fact all forms of matter change, and change is part of the very being of matter. The change may be very quick indeed. Some of the molecules which exist in a flame can only last for a thousandth of a second or less. Other material structures, for example the fossils in old rocks, last for hundreds of millions of years. None last for ever.

We have, of course, no reason to think that this is the last word about matter. A century or two hence our descendants will probably think of it in ways which we cannot yet imagine. The important point is that each new way of thinking about matter increases our control over it. This is the test—in fact the only scientific test—by which we can determine that we are getting nearer the truth.

The Universe gets less Mysterious

NEWTON was something of a disaster for science. Not because he was wrong. On the contrary, he had a habit of being devastatingly right, even in his apparently wilder speculations, such as that about particles of light being subject to "fits". But he left little room for originality in his immediate successors. For nearly two centuries astronomers did little but illustrate, by ever more numerous examples, the correctness of Newton's gravitational theory. And mathematicians used the differential calculus as one of their principal tools, though it was two centuries before anyone was able to justify Newton's intuitions by logical proof. The development of science might have been healthier if Newton's work had been spread out over a dozen men and a hundred years.

His immediate successors became mere commentators on the man "Qui genus humanum ingenio superavit", as his epitaph quite correctly states. Later generations learned at school the very ingenious system of rationalizations by which the commentators had attempted to disguise his inspired guesses as common sense. In the late 19th century, however, facts began to accumulate which showed that Newton's theories were only approximations to truth. And if one had accepted them as dictates of reason, a world in which they did not hold exactly seemed to be irrational or at best mysterious.

I believe this mystery is merely a defence mechanism against bringing our ideas up to date, and that most of the facts of modern physics are as intelligible as those on which Newton built his theories, though we are waiting for an exposition of them as clear as his. Let us take the group of events described as the transformation of mass into energy, and conversely. Some prehistoric genius discovered that many things have a practically constant weight. It is not quite constant. If you put a man on a sensitive balance he can be seen to lose weight so quickly that no two swings are alike. Further, things weigh more when the barometer is low than when it is high, especially if they are bulky. This is explained by the increased buoyancy due to displacement of air. On the other hand the fact that things weigh less on a mountain than in the plain can only be explained as a real loss of weight taking place when they are removed further from the earth which attracts them.

However, Newton found another quantity, namely mass, which is constant when weight is not. The mass of a body is proportional, among other things, to the force needed to give it a given speed when acting for a given time; or to the amount of work which a body will do, when moving at a given speed, before it is brought to rest. According to Newton, the mass of a body was absolutely constant, while the weight varied both with the mass and with the strength of gravitation in its neighbourhood. The idea of energy is also a common-sense idea, at least in a mechanical age. And the acceptance of the theory that energy is conserved, and only changes from one form to another, did not contradict Newton's ideas.

It now turns out, however, that energy has mass and weight. When you wind up your watch you put energy into it. As a result it has more mass. That is to say you have to do more work in accelerating for a sprint with your watch wound than unwound. It also weighs more. That is to say it is more attracted by the matter and energy of the earth than it was before. Or if you like to put it that way, it causes more of a distortion of space-time. Of course these changes in a watch are too small to be measured at present, but changes of this type in atoms can be measured with some accuracy. For the life of me I cannot see anything mysterious in such facts as these. It is no shock to my intelligence that, just as the spin of the flywheel of my car makes it harder to turn it, it also makes it harder to accelerate it.

One of the most famous of 19th-century calculations was that of Helmholtz concerning the solar system. He showed that if the matter in it had originally been cool gas distributed in a nebula reaching to the orbit of Neptune, its contraction could have provided all the energy needed to heat the sun to its present temperature, but that at the present day the energy given out by the sun could only be supplied by gravitation if the sun's radius was lessening by about a mile per century. This was a good theory in its day. It gave a possible rational explanation of the source of the sun's heat, but was unacceptable since it was already sure that the earth's surface had been at near its present temperature for millions of years. Chemical energy was equally out of the question, since if the sun were made of coal, at its present rate of energy production it would only last for about ten thousand years.

So pious astronomers could echo Raphael's words about the sun in Faust:

> Ihr Anblick gibt den Engeln Stärke
> Wenn keiner sie ergründen mag.

I sometimes wonder whether Goethe, when he wrote these lines, was guilty of a low pun, and compared the angels with vegetables that make starch when the sun shines on them. Certainly ignorance is not a source of strength to men, whatever it may be to archangels.

When Rutherford discovered that radio-active transformations gave out millions of times as much energy as chemical changes of the same substances, it was clear that energy sources were available which would account for heat production on a vast scale over millions of years. But there do not seem to be enough of the ordinary radio-active elements in the sun to supply energy for a thousand million years. And until the last few years the nature of the energy-generating process was far from clear.

Then the work of Aston on the one hand, and Cockcroft and Walton on the other, at Cambridge, furnished the necessary clues. Aston, with his mass-spectrograph, found that the weights of atomic nuclei were very nearly whole numbers, when expressed in terms of that of hydrogen. Apparent exceptions were due to mixture. Thus chlorine has an apparent atomic weight of about 35½, and turns out to consist mostly of atoms of atomic weight 35, with a lesser amount of atomic weight 37. Whereas carbon, with atomic weight 12, consists almost wholly of one atomic species. But as soon as Aston's measurements became more precise he found that the whole numbers were not exact. The nucleus of a carbon atom is very probably built up of 12 protons (nuclei of hydrogen atoms) and 6 electrons. But its weight is nearly 1 per cent below the sum of their weights. The lost weight is due to loss of energy. The process of packing protons and electrons together gives out an immense amount of energy, and when this goes off into space as radiation, weight is lost too. The weight of energy has been pretty accurately determined by research on the radio-active elements with heavy atoms, and as it obeys an extremely simple formula there is little doubt that the same formula holds for all mass-energy transformations.

Eddington had calculated the central temperature of the sun at about ten million degrees, though Milne put it somewhat higher. We cannot get such temperatures in the laboratory, for obvious reasons. But a high temperature means rapid random movement of atoms, and we can get atoms moving, though not at random, at speeds corresponding to these great temperatures. Cockcroft and Walton were the first to do so, by passing a current with half a million volts' electromotive force through hydrogen in a near-vacuum.

Under these circumstances atomic nuclei collide with such violence as to be transformed. Some of these transformations involve a loss of mass and a giving out of energy in vast amounts. More accurately some of the mass and energy associated with the particles gets loose, and appears as motion of the particles and as radiation. These transformations only occur at huge temperatures, just as coal does not burn below a red heat. Gradually Atkinson, Bethe, Gamow, and others worked out a theory of the liberation of energy in the sun, based on the actual results of experiments such as those of Cockcroft and Walton.

The essential energy-liberating reaction seems to be the transformation of hydrogen into helium. This does not take place directly, save to a slight extent. The actual process appears to be the successive addition of three hydrogen nuclei to a carbon nucleus, giving an overweight nitrogen nucleus. A fourth collision with hydrogen increases its mass still further, and it divides into a normal carbon nucleus and a helium nucleus. In fact the carbon acts as a catalyst, speeding the reaction up.

At the present rate of shining, our sun's store of hydrogen would last about ten thousand million years. Towards the end of this time it should, rather paradoxically, get hotter, and finally perhaps explode as a Nova. However, physicists are getting more cautious about calculations concerning the very remote past and future. We can only do so if we assume that the "laws of nature", *i.e.* the properties of matter, are unchanging. This seems to be doubtful on theoretical grounds. But just how they are changing is quite unknown. According to Milne's theory, the speed of light, measured in terms of the sidereal year and a standard wave-length, should be falling off by one two-thousand-millionth part per year. If this is correct our measurements are certainly not accurate enough to detect it, though Bray thinks he has detected a much bigger change.

If Milne is right chemical processes are speeding up relative to most physical processes such as the earth's rotation, and we cannot talk with any confidence about happenings more than a thousand million years or so in the past or future. Once again this does not strike me as mysterious. Eternal and unchanging laws are merely human attempts to ascribe to nature some of the alleged attributes of God. A human society whose laws were eternal would be mysterious in the sense that it had supernatural foundations, as Catholics believe to be the case. So would a nature with unchanging laws. However, we shall have to know a good deal more about its contemporary laws before we know how, if at all, they are changing. But it seems likely that we shall be able to escape from the dilemma that either the universe had a beginning and will have an end, or else it is merely a repetition of rather well-worn themes, including the rise and decline of species of thinking animals. It looks as if the universe will turn out to have a real history, but no beginning or end in the sense of a first or last event.

For such reasons as these, then, I believe that the universe should appear less mysterious today than ten years ago to anyone who tries to follow the development of physics. It is more complicated than it seemed, but that is a very different matter. The Newtonian universe was only intelligible as a machine created and set in motion by a creator who then left it alone. The universe of modern physics is something which develops, like its component parts, and for that very reason is intelligible if one regards change and development as fundamental realities.

The Laws of Nature

THE phrase "A law of Nature" is probably rarer in modern scientific writing than was the case some generations ago. This is partly due to a very natural objection to the use of the word "law" in two different senses. Human societies have laws. In primitive societies there is no distinction between law and custom. Some things are done, others are not. This is regarded as part of the nature of things, and generally as an unalterable fact. If customs change, the change is too slow to be observed. Later on kings and prophets could promulgate new laws, but there was no way of revoking old ones. Thus the unfortunate Jews, if orthodox, stagger under a burden of law which was increased over thousands of years by ingenious rabbis. The Greek democracies made the great and revolutionary discovery that a community could consciously make new laws and repeal old ones. So for us a human law is something which is valid only over a certain number of people for a certain period of time.

Some people also believe in Divine laws which hold for all men everywhere. The curious can buy a recent report[1] by Anglican bishops and others who have tried to solve the fascinating problem of where human law ends and Divine law begins as regards marriage with relatives. God forbids you to marry your sister, it appears, but it is not so sure whether it is God or man who says that you may not marry your niece. So many gods have issued so many different laws in the past that a study of history makes the theory of Divine law a little ridiculous. Just the same applies to the Stoic conception of a natural law incumbent on all men as men. Even if such laws existed they would not be eternal, for man has evolved and will evolve. Actually they turn out merely to hold for a particular stage of social and economic development.

Laws of Nature, however, are not commands, but statements of fact. The use of the same word is unfortunate. It would be better to speak of uniformities of Nature. This would do away with the elementary fallacy that a law implies a law-giver. Incidentally it might just as well imply a parliament or soviet of atoms. But the difference between the two uses of the word is fundamental. If a piece of matter does not obey a law of Nature it is not punished. On the contrary, we say that the law has been incorrectly stated. It is quite probable that every law of Nature so far stated has been stated incorrectly. Certainly many of them have. Nevertheless these inaccurately stated laws are of immense practical and theoretical value.

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[1] *Kindred and Affinity as Impediments to Marriage.* S.P.C.K., London, 1940.

They fall into two classes—qualitative laws such as "All animals with feathers have beaks", and quantitative laws such as "Mercury has 13·596 times the density of water" (at 0° C. and 1 atmosphere's pressure). The first of these is a very good guide. But it was probably not true in the past. For many birds which were certainly feathered had teeth and may not have had beaks. And it is quite possibly not true today. There are about a hundred thousand million birds on our planet, and it may well be that two or three of them are freaks which have not developed a beak, but have lived long enough to grow feathers. It was thought to be a law of Nature that female mammals (defined as warm-blooded vertebrates with hair) had mammary glands, until Professor Crew of Edinburgh found that many congenitally hairless female mice lacked these organs, though they could bear young which other females could then foster.

And quantitative laws generally turn out to be inexact. Thus water is nothing definite. It is a mixture of at least six different substances. For in the molecule H_2O one or both of the hydrogen atoms may be either light or heavy, and so may the oxygen atom. Similarly, mercury consists of several different types of atom. Thus the ratio of the densities of mercury and water is not fixed, though in the case of ordinary samples the variation is too small to be detected. But it can be detected if the water happens to have been taken from an accumulator which has been used for some time.

We have, I believe, gained a somewhat deeper knowledge of the meaning of natural laws from the work of two living English physicists—Jeffreys and Milne. In his *Theory of Probability*[1] Jeffreys has something new to say about induction. Two contradictory theories are in vogue as to the laws of Nature. The older view is that they are absolute, though of course they may have been inaccurately formulated. The extreme positivistic view, enunciated by Vaihinger, is that we can only say that phenomena occur as if certain laws held. There is no sense in making any definite statements, though it is convenient to do so.

Now Jeffreys points out that, if a number of observations have been found to conform to a law, it is highly probable that the next one will do so whether the law is true or not. In Jeffrey's words: "A well-verified hypothesis will probably continue to lead to correct inferences even if it is wrong". This can be proved in detail if it is stated with sufficient exactitude, on the basis of some highly plausible assumptions. Thus we can use the "as if" principle without denying the existence of natural laws. What is more remarkable, laws which ultimately turn out to be inexact are often far more exact than the data on which they are based. Thus Jeffreys remarks, speaking of gravitation, that "when Einstein's modification was adopted the agreement of observation with Newton's law was three hundred times as good as Newton ever knew".

Positivists and idealists have made great play with the fact that many laws of Nature, *as formulated by scientists*, have turned out to be inexact, and all may do so. But that is absolutely no reason for saying that there are no regularities in Nature to which our statements of natural law correspond. One might as well say that because no maps of England give its shape exactly it has no shape.

What is remarkable about the laws of Nature is the accuracy of simple approximations. One might see a hundred thousand men before finding an exception to the rule that all men have two ears; and the same is true for many of the laws of physics. In some cases we can see why. The universe is organized in aggregates, with, in many cases, pretty wide gaps between them. Boyle's law that the density of a gas is proportional to its pressure, and Charles's law that the volume is proportional to the temperature, would be exact if gas molecules were points which had no volume and did not attract one another. These laws are very nearly true for gases at ordinary temperatures and pressures, because the molecules occupy only a small part of the space containing the gas, and are close enough to attract one another only during a very small part of any interval of time. Similarly, most of the stars are far enough apart to be treated as points without much error when we are considering their movements.

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[1] *Theory of Probability.* Oxford, 1939.

And most men manage to protect themselves from injury so far as is needed to keep both ears; whereas trees cannot protect themselves from the loss of branches. It is very rare to see a completely unmutilated, and therefore completely regular, tree. Mendel's laws, according to which two types occur in a ratio of 1 : 1 in some cases and 3 : 1 in others, are theoretically true if the processes of division of cell nuclei are quite regular, and if neither type is so unfit as to die off before counts are made. The first condition never holds, and the second very rarely does. But the exceptions to the first condition are very infrequent. In one particular case a critical division goes wrong about once in ten thousand times. The effect of this on a 1 : 1 or 3 : 1 ratio could be detected only by counting several hundred million plants or animals. Differences in relative fitness are more important. But even so the Mendelian ratios are sometimes fulfilled with extreme accuracy, and are generally a good rough guide.

Jeffreys points out that in such cases it is often much better to stick to the theoretical law rather than the observed data. For example, if you are breeding silver foxes and a new colour variety occurs which, if crossed to the normal, gives 13 normal and 10 of the new colour, you are much more likely to get a ratio of about 1 : 1 than 13 : 10 if you go on with such matings, even though if you breed many thousands the 1 : 1 ratio will not hold exactly. The mathematical theory which Jeffreys has developed concerning such cases is particularly beautiful, but can hardly be summarized here.

Milne's theories are extremely revolutionary. He starts off with very simple postulates. He assumes some geometrical axioms—for example, that space has three dimensions—but does not assume Euclidean geometry. He also assumes what he calls the principle of cosmological relativity—namely, that observers anywhere in the universe would see much the same things. There is no favoured point or centre, no limit beyond which there is no more matter, and no direction in which matter progressively thins out. This is an assumption; however it is only the natural extension of Copernicus's theory that the earth is not the centre of the universe, but just one star among others.

He then imagines observers on different stars communicating by light signals. This is, of course, unrealistic. But I have little doubt that, if his cosmological views prove valuable, later workers will be able to replace it by a more realistic hypothesis. Given this possibility of signalling, and clocks, he shows how the observers can graduate their clocks and establish a geometry. There is nothing very surprising in this. What is remarkable is that Milne claims that he can deduce some physical laws as necessary consequences of his basic assumptions. In particular he deduces a law of gravitation which reduces to Newton's at "small" distances measurable in units less than thousands of light-years.

This does not seem impossible. The law that the angle in a semi-circle is a right angle was first observed as being at least very nearly true. Then twenty-five centuries ago Thales opened a new era in human thought by proving that it must be true. Milne may be a new Thales. Of course, later mathematicians showed that Thales, and Euclid too, had made a number of concealed assumptions. The proof was not as simple as they thought. And even if Milne's theories meet with no stronger criticism they will doubtless meet with this one.

Milne claims that some, and perhaps all, physical laws are inevitably and rationally linked. He accuses those who say that laws might be otherwise of using "magical", not rational, thinking. Dirac goes even further, and suggests that there is nothing chancy about the distribution of the matter in the universe, and that an all-wise mathematician could deduce this too from a few postulates. I must say I find this much harder to swallow. Laplace's theory, that given a full knowledge of the universe at one time one could deduce its state at all times past and future, was difficult enough to believe. This is worse. But in so far as any elements in these theories are accepted this will be a signal triumph for rationalism as against theories which recognize an irrational element in the universe.

However, if Milne simplifies natural laws with one hand, he complicates them with the other. Lengths may be defined in two ways. They may be referred to a material object, such as the standard metre, or to a wave-length of light, which has the merit that it can be reproduced anywhere. If all the standard metres were lost, they could be reproduced with an accuracy of about one in thirty million by reference to known wave-lengths such as that of the red cadmium line derived from spectroscopic observations. One result of Milne's calculations is that the length of the metre, measured in standard wave-lengths, is increasing by about one part in two thousand million per year. If you like, you may say that the universe, including the standard metre, is expanding. But it is simpler for most purposes to say that atoms are vibrating quicker. It makes not the slightest difference to any observable phenomenon which of these statements you choose. In fact, on this theory, and indeed on several others which have been worked out in less detail, many of the laws of Nature are changing. There is nothing arbitrary or haphazard about this change, but simply an increase in certain physical constants with the time.

This has important philosophical consequences. If true, it rules out any theories of a cyclical or recurrent universe. At a sufficiently early date the properties of matter were so different, and in particular chemical processes so sluggish, that life must have been impossible; or, to be accurate, material systems similar to any existing organisms could not have lived. Thus we can see why, even if the universe had no beginning, life has not got very far yet. And in the far future life will also be impossible for beings constituted like ourselves, though it may be that our descendants will keep up with changes in the laws of Nature by natural or artificial evolution.

Once again, I am sure that Milne's theories, even if they are partially correct, will turn out to be too simple for the immense complexity of the real world. But they give us at least an inkling of how posterity will think of natural laws. So far from being laid down by the arbitrary word of a creator, they may prove to be a system as intimately and rationally knit together as the propositions of geometry, and yet changing and evolving with time like the forms of plants and animals.

Cleomenes and Christ

IT is obvious to any intellectually honest man or woman that the gospels cannot be completely true, for the very simple reason that they contradict one another. This is, of course, independent of the difficulty of believing accounts of miracles, which would remain if there were only one gospel. To one who approaches the gospels unhandicapped by a Christian education, they are obviously highly suspect. But many people educated as Christians would have been able to accept the miracles if the accounts of them, particularly those of the resurrection, had agreed. In fact, from a rationalist angle, it might almost be said to be providential that the Church accepted four gospels, and not one; for this rendered some kind of criticism inevitable as soon as it was possible without the certainty of death as the penalty.

Most biblical critics have been intensely interested in religion, so that they had a fair knowledge of non-Christian religions. So when it was admitted that the bible was not wholly true, and a search for sources began, it was natural that they should first turn their attention to non-Christian religions. Thus T. H. Huxley drew attention to Itnapishtim, the Chaldean prototype of Noah, and J. M. Robertson in *Pagan Christs* pointed out the number of incidents in the gospels which were paralleled in earlier accounts of non-Christian saviour-gods. I do not, I hope, underrate the importance of this work, but in this article I wish to suggest that there are other equally important pagan sources, and that the affiliation of Christian to pagan myth may often have been a secondary one.

It makes no claim to originality. It is intended to call the attention of rationalists to the theory which was first presented imaginatively by my sister Mrs. Mitchison in her historical novels *The Corn King and the Spring Queen*, and *The Blood of the Martyrs*, and later in a more scholarly manner by A. J. Toynbee in volume 6 of *A Study of History*.[1] These authors point out the extraordinary number of analogies between the story of Jesus' last days, and those of a group of historical figures.

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[1] Oxford University Press, 1939.

These figures belong to three groups. Agis and Cleomenes were kings of Sparta in the 3rd century B.C. who attempted to restore the ancient political and economic equality of the citizens of their country. Tiberius Gracchus, Gaius Gracchus, and their companion Marcus Fulvius Flaccus, made similar attempts in the Roman republic. Lucius Sergius Catilina was more openly revolutionary, and Marcus Porcius Cato (minor) was one of the last defenders of the republic against Julius Caesar. Aristonicus was a possibly illegitimate member of the royal house of Pergamus in Asia Minor who founded a "city of the Sun" in which equalitarian principles were put into practice, and which was soon destroyed by the Romans. Athenio, Eunus, and Salvius were leaders of slave revolts in Sicily. The objectivity of the analogies found is, I think, supported by the fact that Dr. Toynbee is a Christian, whilst Mrs. Mitchison is not. Thus any bias in these authors will tend to work in opposite directions.

The reason why the very remarkable correspondences in the stories were not earlier stressed is, I think, to be found in two historical facts. In the first place the earlier students of Christian origins were more learned in religious than in secular history. In the second place they had not been appreciably influenced by the Marxist theory of the class struggle. According to this theory the struggle between classes within states has, for the last several thousand years, been the main motive power behind historical events. Neither Mrs, Mitchison nor Dr. Toynbee are Marxists, but each has been influenced by Marxism, as have the vast majority of thinking men and women of our time.

It is quite clear that the class struggle is one source of the ideas of the gospels. Throughout them the poor are represented as morally superior to the rich. They are told that they are going to triumph over their oppressors. However this triumph will occur in another world, as with Lazarus and Dives, or after this world has been transformed, not by a human revolutionary effort, but by a divine miracle. If the gospels have many different sources, as seems pretty certain, it is of course quite possible that some of these were a good deal more revolutionary than the existing documents, and that the "left" elements may have undergone a process of censorship.

Christianity spread among men and women who were dissatisfied not only with themselves, but with the world. St. Paul did his best to centre the Christian life round dissatisfaction with oneself, that is to say a conviction of sin. He was largely successful, and in consequence we probably underestimate both the extent of the revolutionary component in primitive Christianity, and the cheerful character of most primitive Christians. For not only was Jesus described (if the gospels are to be believed in this matter) as a gluttonous man and winebibber, but in my own experience men and women who subsequently die for their convictions (as a fair number do today) are considerably jollier than the average.

But let us turn from these questions to the correspondences. We must realize, to begin with, that the stories of such men as Cleomenes and Catiline, as they have come down to us, are highly mythical. These men were certainly historical figures, and Jesus may not have been one. But the story of Cleomenes' death, as given by Plutarch, who probably wrote later than St. Mark and earlier than St. John, seems to be taken from an older writer, Phylarchus, who lived in Egypt during the 3rd century B.C. and is said by the slightly later Polybius to have distorted the truth in the interest of his hero Cleomenes. On the other hand we only know of Catiline through his political enemies such as Cicero. The authors of the gospels had almost certainly not read books on the lives of such men as these, but it is highly probable that, as members of an oppressed class, and personally conscious of their oppression, they were acquainted with the stories of their lives and deaths.

Toynbee lists no less than 87 points in the gospel story of Jesus which are paralleled in those of one or more of the pagan heroes. Of these 26 occur in the story of Agis, and no less than 38 in that of Cleomenes. The next highest score is that of Tiberius Gracchus with 15 resemblances. The main points of resemblance to Cleomenes are as follows:

Royal descent, a fore-runner, a mother who (according to St. John) believed in him, denunciation of the ruling class, proclamation of a new society whose membership is based on merit, not birth or wealth, personally a middle course between luxury and asceticism. Such are resemblances in the earlier parts of the stories. Naturally enough they lead up to an attempt by the authorities to kill the hero, which is difficult because of the hero's popularity. I do not regard these resemblances as very striking. The resemblances in the last days are of a wholly different character. Each hero has had a last supper with twelve companions on the night before his death. At each supper one of the twelve lay on the hero's breast, and a traitor went out. However the traitor to Cleomenes was not one of the twelve, but a slave. Soon after this they meet the forces of law and order, and shed a little blood with a sword or swords. But the hero commands his followers to cease fighting (in Cleomenes' case because the people of Alexandria will not rise in his support). The hero is mentioned as wearing a seamless shirt. He is crucified (in Cleomenes' case after death). A miracle occurs (in Cleomenes' case a great snake winds itself round his head). Hence he is hailed as the son of God (in Cleomenes' case "A hero and child of the Gods"). The victim is afterwards given religious veneration, and pilgrimages are made to the place of crucifixion. The victim is not mutilated, as was usual, and gives a sign of life (in Cleomenes' case a twitch) when pierced after his apparent death.

Toynbee further lists 14 close verbal correspondences between the gospels and the stories of the pagan heroes, of which 6 are with the story of Cleomenes. Quite frankly I think that he has slightly overstated his case, as I consider that Drews, Robertson, and other christologists, have done in the past, even though he might have added another parallel, a flight from enemies into Egypt. Nevertheless the case is sufficiently impressive to make me at least fairly sure that the legend of Jesus' last days is in part derived from that of Cleomenes, just as the legend of his early days, including the episodes of Simeon and the diabolic temptation, is in part derived from Hinayana Buddhist sources.

Further, a certain number of the analogies between Christ and pagan divinities may be derived indirectly through Cleomenes. The Spartan kings were supposed to be descendants of Heracles. Cleomenes, who on the whole looked to the past for inspiration, probably took this seriously, and identified himself with Heracles to some extent. So probably did his biographers. The analogy of Christ and Heracles was of course obvious even to some of the fathers of the Church.

The resemblances to Agis, another revolutionary Spartan king, are very striking. For example Amphares' betrayal of Agis resembles Judas' betrayal of Jesus in several details, and Agis was hanged (not crucified) with two others. If I do not give these or other resemblances in detail I must remark that Toynbee devotes 164 pages to his argument.

How were these stories transmitted to the compilers of the gospels? It is very unlikely that an early Christian had read Phylarchus or Plutarch, and deliberately incorporated incidents from their works into a proto-gospel. Mrs. Mitchison makes the brilliant suggestion that these legends were passed down among the illiterate slaves and proletariat of the Roman Republic and Empire not only orally, but by pictures. Prof. Toynbee develops this suggestion without reference to her work, and may have reached the idea independently. He illustrates the frequency of Graeco-Roman mural and other paintings of episodes both historical and mythological, by a wealth of example. Once such pictures were emotionally associated with social unrest and aspirations for a better society, they might very easily, and perhaps even without deliberate falsification, be transferred from one legend to another, as, for example, the clothing and scenery of pictures of the same religious episode varies from age to age.

In this way Toynbee explains a number of curious and often irrelevant episodes in the gospels. For example the story of the young man who left a robe of fine linen in the hands of the officers of the Sanhedrin and fled naked could be based on a picture of Tiberius Gracchus leaving his toga in the hands of an assailant and fleeing in his shirt, and Pontius Pilate's washing of his hands could be based on a similar action by Catiline.

"These scenes", writes Toynbee, "which he had failed to knit up into the main fabric of his work may have been virtually impossible for him to leave out for the reason that his public may have expected to find them in any *Volksbuch* in which the hero was presented in the role of a saviour." Rationalists will find it harder to follow him when he suggests that God may reveal himself through folklore as well as through history. If God is revealed through unconscious or semi-conscious falsification, why not through deliberate falsification? Mrs. Mitchison has no doubt embellished the story of Cleomenes even further than did Phylarchus or Plutarch. But she does not claim that her novels are history, much less revelation.

The fact is, I suppose, that in the last few centuries our standard of truth has risen, not because of any great moral reformation of humanity, but because science is only possible if what many people regard as a meticulous attention is paid to truth. Scientists learned the importance of accuracy from manual workers, not from philosophers or historians. In some of the work which I am undertaking at present my life quite literally depends on an almost slavish respect for facts. If I had distorted certain facts in a way which might have suited my preconceived notions I should now be dead, instead of merely having had convulsions. I find it difficult to suppose that, if we can only reach the truth about parts of the universe by extreme accuracy, folklore is likely to help us to the truth about the universe as a whole.

However this may be, Dr. Toynbee has, I believe, done a service to truth. He has thrown a new light on the origins of Christianity. He has also helped in a field of investigation which is likely to become more important as Christianity becomes less so, the study of the lives of the poor and illiterate workers who formed the vast majority in the Roman Empire. The New Testament, and particularly the gospels, stands out from the rest of ancient literature by its peculiar directness and vigour. This has been ascribed to its divine origin. But it can be explained more convincingly by the fact that the books of the New Testament are the only ancient books that have come down to us which were written by proletarians for proletarians about proletarians. The workers' movement in the Roman Empire finally developed into the Christian Church, which abolished or absorbed its competitors, and finally sold itself to Constantine, leaving the workers little better off. It is of great importance today to study how this movement developed, how it was canalized into a religious channel and finally betrayed. Perhaps a study of these events may help the workers' movement of our own time to avoid a similar fate.

In this connection it is necessary to study the origin of various Christian doctrines. "Clericalism", wrote Lenin,[1] ". . . of course has epistemological roots, it is not groundless; it is a sterile flower undoubtedly, but it is a sterile flower that grows on the living tree of fertile, genuine, powerful, objective, absolute human knowledge." A geneticist can increase his knowledge of fertility by studying sterile flowers, such as those of double stocks. And those who are most concerned with human progress and with absolute truth cannot neglect to study the sterile flowers of theological dogma.

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[1] *Selected Works*, vol. 11, p. 85.

The Argument from Design

I HAVE recently been reading Paley's *Evidences of Christianity*, as every good rationalist should. Paley attempts, with very great skill, to prove the existence of a creator from the design of living organisms.

Of course a good many of his arguments were met by Darwin. It is clear that, given the facts of heredity and variation, organisms tend to adapt themselves to their environment without any conscious planning by themselves or anyone else. But it is by no means proved that the whole course of evolution from single-celled organisms to oaks, daisies, ants, and men can be explained on these lines.

There are real difficulties in the evolution of such an organ as the eye, where many parts must vary together to produce an improvement. I have tried to meet them from a neo-Darwinian standpoint, but my argument is not so strong as the general argument for natural selection. Again the evolution of instincts presents great difficulties. They cannot be inherited memories in the most interesting case, that of social insects. For since the ancestors of worker bees and ants were not workers, the workers have instincts quite different from any of their ancestors. The chemical organization of a cell is immensely complicated, and it is hard to see how an organism could work at all unless it were of extreme chemical complexity. If so the very first steps in evolution are the hardest to explain.

I think therefore that a reasonable man should be prepared to examine arguments which assume a measure of design in living creatures, even though I do not personally think that they are cogent.

Now Paley imagined an intelligent savage picking up a watch, and concluding that it had been designed. He then argued that animals show far more evidence of design than watches. And he next argued that the designer had many of the characters of the god whom he worshipped.

To my mind his argument leads to a radically different conclusion. Let us suppose an intelligent savage to come upon one of the African battle-fields of the present war, and to examine tanks, artillery, rifles, land mines, and other weapons left behind in the desert. He might well conclude that these weapons had been designed. But a slight further exercise of intelligence would convince him that they had not all been designed by the same person or group of persons. He would conclude that the British weapons had been designed to destroy the German ones, and conversely. He might have a little difficulty if he got evidence that the Germans and Italians had had a scrap on their own, but we may omit this complication.

Now the most conspicuous features of animal organization are those which are designed (if they are designed) for competition with other living creatures, and often for their destruction. All animals live by eating other animals or plants. They may kill them, as we kill rabbits and potatoes, or merely eat parts of them, as we eat parts of the apple tree and the flea drinks parts of us. A few, such as the blow-flies, beetles, and "worms", actually mostly insect larvae, which eat our bodies if they get the chance, only eat dead food, apart from bacteria. And these exceptional pacifists are not the noblest of animals. The plants generally compete by pushing rather than biting. Look at a plantain spreading its leaves over the grass of your lawn, or a tree cutting off the sun from the plants below it till they die. Though only a few plants, like the sundew and the mistletoe, actually eat other living things, they are all engaged in a merciless struggle for life.

Of course biologists have devoted much of their time to the internal coordination of organisms. If this is attributed to a designer it shows very great ingenuity, and no malice. However a tank resembles a motor car or a tractor in many of its features. But its essential function is to carry a gun for the purpose of destruction. And when we consider animals, not in terms of the relations of their parts, but of their relations to other animals, the same is true of them.

If then, animals were designed, they were designed for mutual destruction. If there was one designer, he is or was a being with a passion for slaughter like that of the ancient Romans, and the world is his Coliseum. A much more reasonable consequence of the hypothesis of design is polytheism. If each of the million or so animal species were the product of a different god, their mutual struggle would be intelligible. One must particularly admire the ingenuity of the creators of some of the parasites, particularly those with several hosts. For example the digenetic trematode worms such as *Bilharzia*, which pass one generation in a water snail, and another in human beings, causing an extremely painful chronic disease often terminating in cancer, are amazing pieces of work. So are the malaria parasites, which live alternately in mosquitoes and human blood.

A seaman dying of thirst on a raft may well curse Whitehead, who invented the torpedo. Trematode larvae surrounding a water snail and ramming their front ends into it look remarkably like little torpedoes when seen through a microscope. And unlike the human creation they multiply inside their victims and produce another generation which kills men or sheep. In fact Whitehead was a mere amateur compared with the creator of *Bilharzia*.

Wherever Paley's argument leads, it does not lead to Christianity. If pushed to its logical conclusion it forces us to believe in a malignant creator, or more probably, in a number of malignant creators. Certainly this creator or these creators are not wholly malignant. The world of life contains a great deal of beauty and pleasure. But one can only admire the beauty by closing one's consciousness to the pain and injustice which are bound up with it. A biologist who has spent his life in the study of parasitic animals must inevitably smother his feeling of pity to some extent, and tend to take human misery and injustice for granted.

But the moral effect of the belief that the world was made by a benevolent and almighty creator is vastly worse. Mr. Lewis's recent book *The Screwtape Papers*, is a good example of its effects on an intelligent man. The book is supposed to be written by a devil. This devil is strongly in favour of modern medical practice, which in many cases has robbed death of its pain and terror. He is by no means enthusiastic about war, which gives many people the experiences of suffering needed to turn their minds to God.

If the world of nature is God's plan, then attempts to banish pain are contrary to this plan. So are attempts to perfect human society by eliminating the various evils which men inflict on one another. The religionist can point out the impossibility of eliminating cruelty and injustice completely. Nor can one eliminate pain completely. But it is possible to reduce it to such a level that for years one may have no pain which interferes with normal action and thought. And Marxists, among others, believe that by applying scientific method to human affairs, it will be possible to cut down injustice and cruelty to a similar extent. All Buddhists, most if not all Hindus, and most Christians, believe this to be impossible, and further, that it is a dangerous illusion to think it possible. Conversely those who think that the establishment of "heaven on earth" is something worth trying, must regard the religions as dangerous illusions, whatever services they have rendered to men in the past.

Darwin made it reasonable to reject the argument from design, and the evil God or gods to which it leads, if carried to its logical conclusion. We have not yet realized what an immense advance in our moral ideas this has rendered possible. Naturally enough many of the early Darwinists retained the veneration for nature which is justifiable if it is God's handiwork. They therefore used Darwinism to justify various forms of human struggle, including war and unrestricted economic competition. T. H. Huxley, by contrasting the ethical process and the cosmic process, did his best to combat this tendency. But as he took so much of the structure of the society in which he lived for granted, he underestimated the power of the ethical process.

Today we see that cut-throat competition, both between species and to a less extent within them, was a necessary condition of evolution. We also see that it is so no longer. We can control the evolution of animals, and make unprecedented creatures, such as the Jersey cow and the Angora rabbit, for our needs. We shall be able to control our own, though very fortunately we do not yet know how to do so. My own most important scientific work has been to accumulate some of the preliminary knowledge, for example to map some of the genes on a section of one of the 24 pairs of human chromosomes. It is abundantly clear that the amount of such preliminary work needed is so great that we shall not have the necessary knowledge for some centuries. By this time a Marxist may reasonably hope that human society will be so far improved that there will be agreement on the innate characters desirable in man, and willingness to alter our breeding habits accordingly.

We can look ahead of this. If human society is brought near to what we should now regard as perfection in the next few thousand years, our descendants will find nature pretty revolting. The scream of a rabbit caught by a weasel will be as horrible as that of a rabbit in a trap to sensitive ears today. If we abolished weasels, sportsmen, and other enemies of rabbits today, rabbits would increase till they did vast damage to crops and trees, and were finally kept down by disease and starvation. Over-production, as Darwin saw, is a universal character of living things, and a necessary condition for natural selection. To abolish the needless pain of nature we should need to check this over-production, as we already do to some extent with our domestic animals. The lion and the lamb will be able to lie down together when we can provide the lion with a diet high in proteins not derived from lambs, but from vegetable or synthetic sources.

Speculations of this kind may seem ridiculous in the middle of a war. I believe that they are justified because we are apt to think that since widespread misery is part of nature, it is therefore unavoidable. Those who are opposed to a radical reconstruction of human society naturally take this view.

It is also important that rationalists should examine the arguments brought forward in favour of various religious dogmas, and see where they really lead. Defenders of religion invariably stop in the middle. Thus the argument from design leads on to polytheism; the principal arguments for the immortality of the soul also prove that it is not trammelled by space, and therefore omnipresent. The argument, which is an essential part of Catholic theology, that God must have founded an institution to proclaim his will to mankind leads directly to atheism. For if there is such an institution it must be the Catholic or the Orthodox church. And their records prove that they are far from divine. Similarly an idealist cannot logically stop short of solipsism.

It is essential that we should study the economic and social origins of religious beliefs, and the irrational but profound psychological needs which they partially satisfy. But as long as these beliefs are alleged to be capable of rational proof, it is our interesting, and sometimes amusing, duty, to study these alleged proofs, and to see what, if anything, they really prove.

Planets of Other Suns

COPERNICUS, who died four hundred years ago, made it highly probable that our earth and the other planets go round the sun. Soon after his death other scientists suggested that the fixed stars were bodies like the sun, surrounded by their own planets, some of which might harbour intelligent animals like man. This was one of the opinions for which the Pope's executioners burned Bruno.

In the 18th century, materialists generally believed that there were man-like creatures on other stars. This belief was strengthened when, in the early 19th century, the distances of some of the fixed stars were measured, and it was found that they gave us about as much light as the sun would do from the same distance.

However, even a large planet moving round the nearest of the "fixed" stars could not be seen or photographed with any existing telescope, much less with those of fifty years ago. And astronomers found it very hard to explain how planetary systems could originate. A collision between two stars, or a very close encounter, might account for a family of planets, but it is unlikely that they could arise through the condensation of matter originally dispersed round a star. The stars are so far apart that collisions or close encounters are very rare.

So some astronomers took the view that our own planetary system was unique, or very exceptional. If so, it could be argued that, in spite of appearances, our earth was the most important object in the universe. Curiously enough, this argument was used in support of religious beliefs, although of course Christianity, Islam, and other religions agree in teaching that our world was created much as it is now. So any argument based on its being due to a chance collision is definitely anti-religious.

In June 1943 a discovery was made which suggests that, after all, planets may be quite common, and that perhaps the majority of stars may possess them. K. Strand, of Swarthmore

Observatory, in Pennsylvania, made a very accurate series of *observations* on the movements of double stars. Double stars, that is to say, pairs of stars about as heavy as our own sun, and revolving round their common centre of gravity, are quite common. To the naked eye they look like a single star, but a moderately good telescope separates them.

One of the nearest pairs is in the constellation of the Swan, and is called 61 Cygni. Strand found that the distance apart of these two stars did not vary in the regular way which had been calculated. But the irregularity could be explained if a large planet were moving round one of them. For it is not strictly true to say that a planet revolves round the sun. They both revolve round their common centre of gravity. For example our sun does not move in an almost straight line relative to the neighbouring stars. It follows a slightly tortuous path because of the gravitational attraction on it of the planets. Strand calculated the mass of the body which was throwing the star out of its predicted path, and found that it was about 16 times that of the planet Jupiter. It is a good deal nearer to its sun than is Jupiter to our own, and moves in a less nearly circular orbit.

Two other double stars show irregularities of the same kind, but the measurements are not exact enough to determine the mass of the planets as yet. They do show that planets are not uncommon. In another ten years we should know the masses of a number of further planets of other stars, and, above all, Strand's theory will have been tested by prediction, as every scientific theory worth anything must be tested. Very likely Strand's planet is not suited for life any more than are most of the planets moving round our own sun. But if even one star in ten in our own galaxy has planets, there must be millions on which life is possible, and probably many thousands where it has developed further than on earth.

In his *Dialectics of Nature* Engels stated his belief that this was so. Many centuries will probably elapse before we have any direct evidence of life in other planetary systems than our own. But we can certainly say that recent work makes it more probable.

If there are intelligent beings in other worlds, this does not lessen our responsibility for our own world. It does mean that we have less reason than ever to regard the opinions of eminent men of the last two or three thousand years as "eternal values". They are the opinions of inhabitants of one particular world at one particular period of its history, the period of class society, which is now coming to an end. The study of astronomy may make man feel small in comparison with the universe, but it should also make him feel great when he considers his responsibilities. We are fighting today not merely for ourselves and our children, but for the future of the star on which we live.

Mr. Bolfry and the Sun

LAST week I went to James Bridie's *Mr. Bolfry*, which is about two bored soldiers who conjure up a devil in a Free Church Manse in Scotland. I didn't think it was as good as *Dr. Faustus* or *Man and Superman*, let alone *Faust*; but it is rather hard to fit the devil into a play of the present day.

However, I thought the non-miraculous portion was quite a good show, and particularly enjoyed a conversation where the minister got the better of his sceptical opponents. As a counterblast to doubters of the story of Jonah, he produces the life history of the liver fluke, which he gets badly wrong, as a minister well might. But neither the other characters in the play nor the dramatic critics know enough biology to catch him out. In fact Mr. Bridie pulls his audience's leg rather neatly.

The Reverend Mr. Macrimmon also asks a young woman how far off the sun is, and when she answers "90 million miles", she has to admit that she believes an important fact about the world without any idea of the evidence for it. And if she swallows that whole, why not the biblical stories of the creation and flood! The moral is that if you must argue with clergymen, you had better know some science.

Without being an astronomer, I could have given the Wee Free Minister four reasons why people believe that the sun's average distance is about 90 million miles. I assume that for purposes of argument he would grant me that the rough shape of the solar system is known, that is to say that the planets go round the sun in nearly circular orbits, that of Jupiter being nearly five times as long as the earth's, and so on.

In that case we can calculate any distance within the system if we know one, for example, that between the earth and Mars at one particular moment. And this can be obtained on the principle of the ordinary range finder. The gunnery officer on the *Duke of York* got the *Scharnhorst*'s range by looking at her through a range-finder so designed that the angle between the rays of light coming from the *Scharnhorst* to two points on the *Duke of York* enabled the distance to be calculated automatically. In much the same way we automatically judge the distances of near objects from the fact that they look a little different from our right and left eyes. If a planet, say Mars, is photographed at the same time from England and South Africa against a background of faint stars, it appears in slightly different positions, just as an object 10 feet away does against more distant things when we shut one eye at a time. More accurate results are obtained with smaller planets, invisible without a telescope, which come nearer to us than Mars. But all measurements give much the same answer for the size of the solar system. However, the history of science shows that there may be some error common to a whole class of measurements, so it is always well to check them by some other method.

The planet Jupiter has a number of satellites which go round it as our moon goes round the earth. Some of these often enter its shadow and are eclipsed. The times of the eclipses were calculated, but the eclipses are about a quarter of an hour late on schedule when Jupiter is furthest away from us. This lateness is exactly explained by the fact that light takes about a quarter of an hour to cross the earth's orbit. And as the speed of light can be measured in a laboratory, this gives us our figure of 90 million miles by an independent method.

Again as our planet moves through space it sweeps up little particles of stone or metal which we see as shooting stars when they enter the air at high speed and flare up. As the earth's rotation on its axis is related to its passage round the sun in the same way as the spin of a ball-bearing to its motion round the axle, we can see that the largest number of shooting stars from vertically overhead are to be expected about 6 A.M. This is borne out by actual counts, and observations on the speeds and numbers of shooting stars show that the earth is moving at about 18 miles a second, as it must if it moves round an orbit of 180 million miles across, each year. The estimate is not very accurate, but it is clear that the speed is not far from this value.

Again, light reflected from an object moving towards us is a little bluer than if it were stationary, that from a receding object a little redder. For the waves are crowded together by the approach, since each one has a slightly shorter distance to travel than the one before it. Once more, this principle gives about the right speeds for the relative motions of the planets.

A number of other figures agree, for example a comparison of the earth's gravitational pull on the planet Mars with its known pull on the moon. But one attempt to get an estimate of the earth's speed gave the wrong result. In the 19th century it was thought that light was transmitted through the ether, which was fixed, while material bodies moved through it. If so it would be possible to compare the apparent speeds of light in the direction of the earth's motion and in the opposite direction. The latter should have been bigger, just as a wind seems faster if you are cycling against it. But Michelson and Morley found they were the same, and it took the genius of Einstein to explain why this was so.

That is why it was important to confirm the estimate of the sun's distance in as many ways as possible. The range-finder principle turned out to be quite reliable. And we are getting more and more evidence that the same principle holds for the distances of the farther stars, using the diameter of the earth's orbit, 180 million miles, instead of the 6000 miles or so between two points on the earth, as a base line.

I should like to have a chance of debating the questions which Mr. Macrimmon raised in the play with a well-informed clergyman. Unfortunately such debates are not held in this country. In 1918 the present Metropolitan of the Orthodox Church of Russia held public discussions with the Soviet commissar Lunacharski, and they drew big audiences. Unfortunately the B.B.C. was always chary of broadcasting discussions on really important matters, whether of politics, economics, or religion, and has now given them up completely. I hope that as soon as the B.B.C. governors cease to represent Big Business, free discussions will be allowed, particularly on the basic tenets of religion. This would lead to a higher standard of accuracy both by the clergy and their opponents, and clear up a lot of sloppy thinking which does no good to anyone.

Naming the Stars

FIRE watchers get to know the look of the stars, even if they do not learn their names. When the *Daily Worker* is a full-size eight-page paper it will probably publish a star map several times a year, with notes on the positions of the planets, and other matters that change from time to time. But by then the majority of our city dwellers will see little of the stars.

Without a map it is hopeless to try to teach star naming. But I have been asked to write something about the names, for the benefit of those who know them. There are 78 named constellations, or groups of stars, though only about half of them are visible from England. Primitive men probably had names for a few striking groups, both large ones such as the Plough and Orion, and small ones such as the Pleiades. Naturally they were called after a fancied resemblance to common objects. Thus Orion and Canis Major were called a hunter and dog in the northern hemisphere. In the southern hemisphere they are seen upside down from a European point of view, and the dog becomes a boat, the hunter a net let down from it, in Maori mythology.

Most of our names are derived from the ancient Greeks, and the constellations visible from Greece were described about 350 B.C., along with some only visible from further south. Naturally those round the South Pole were not named, so there is an empty space on a Greek star map. But this empty space is not round the present South Pole, or that of 500 B.C., but round the South Pole of about 3000 B.C. For the pole of our earth does not always point in the same direction. On the contrary, it traces out a circle in the sky, with a period of 26,000 years. The present pole star is a fair guide to the true north, being only one degree away from the true pole. It was not such a good guide 2000 years ago, and will not be 2000 years hence. In 13000 B.C. Vega, a bright star in the constellation called the Lyre, was pole star, and will be again in A.D. 13000.

So the constellations in the north, round the equator, and immediately south of it, must have been named nearly 5000 years ago, almost certainly in Iraq. The Greeks gave many of them new names, but stuck to the old arrangements. The sun, moon, and planets all appear to move along a path among the fixed stars called the zodiac. Some peoples, such as the Arabs, divided it into 29 "houses", so that the moon moved into a new one every night. The Babylonians and Greeks divided it into 12 signs, so that the sun is in a different one each month. We have adopted their scheme, though only two of the constellations, the Scorpion and the Crab, remind me of the animals after which they are called. Many of the constellations outside the zodiac were called after figures in Greek mythology.

When Europeans sailed to South Africa and South America they saw a number of unnamed constellations, and these had to be named. In addition a few names were given to spaces in the northern sky with no bright stars. There was considerable competition. An English astronomer tried to call a group of stars "Robur Caroli", after the oak tree where Charles II hid after his defeat at Worcester; but this name did not stick. The only modern figure to get a place in heaven was the Polish king John Sobieski, who saved Vienna from the Turks in 1683, and whose shield is a southern constellation. Many of the southern constellations were named by a French astronomer called de Lacaille in 1763, and have names such as the Telescope, Microscope, Airpump, Octant, and Compass.

In 1627 Schiller attempted a revolution. Heaven was to be made Christian. The signs of the zodiac became the twelve apostles, Orion's dog was called David, Andromeda the Holy Sepulchre, and so on. But as far as names are concerned, heaven has remained pagan. In June 1943 Mr. Herbert, M.P., made suggestions which are probably likely to meet the same fate as Schiller's.

Besides the constellations, a few fixed stars have names of their own, mostly Arabic, for example Algol, meaning the demon, a variable star in Perseus, whose light is dimmed every 69 hours by an eclipse. The brighter stars are named by a

Greek letter and the name of the constellation to which they belong. For example Algol is called Beta Persei. Others are called by Roman letters and numbers, but the fainter stars are listed by two numbers corresponding to latitude and longitude.

Why has not this ancient system been superseded by a more scientific one, as with animals, plants, and minerals? One reason is that the constellations are not natural groups. They are merely sets of stars which happen to be in nearly the same direction from the sun at present, though one star may be a hundred times further off than another. There are natural groups of stars. Thus all the Pleiades are at much the same distance, and the five central stars of the Plough, with Sirius, are moving parallel to one another. But only a few stars can be grouped in this way. So at present one can suggest no satisfactory method of renaming the stars.

Perhaps in the future, when men have agreed among themselves as to what is most worth commemorating, the stars will be named afresh. Thus the Hyades might be called Newton's Prism, Orion Lenin, and the Swan the Aeroplane. But we do not know what human achievements posterity will wish to honour, and we have many more important things to do at present.

Even if the constellations are named afresh, they will gradually change their shapes and break up. If a competent astronomer from ancient Babylon could be resurrected today, he would certainly notice a slight change in the shape of the Plough. In a hundred thousand years the constellations will probably be unrecognizable. But long before that time our descendants will probably know enough about the stars to name them in a more rational manner than after Greek demigods and out-of-date scientific apparatus.

• 3 •

MATHEMATICS

Machines that Think

EVERY anti-aircraft battery includes a predictor. This is not a mathematician, but a machine which, when pointers on it are turned so as to correspond to the direction, height, speed, and so on, of an enemy aeroplane, predicts where it is going next. More accurately it tells the gunner the direction, angle of elevation, and fuze setting, needed to bring it down. Corrections are made for the wind speed and other factors.

Of course the aeroplane is seldom brought down, partly because the observations are seldom quite right, and still more because the pilot who is being shot at may change his course while the shell is in the air. And a modern bomber travels at quite an appreciable fraction of the speed of a shell, so he has the needed time. Fortunately a doodlebug cannot dodge.

The necessary calculations would take an expert some minutes, or even hours, to do, yet the machine does them in a fraction of a second. The predictor is one of a number of machines which today are doing work which was supposed to be possible to the mind only. For in mathematics theory got divorced from practice for a long time, and has still not been fully united.

We know a good deal about how mathematics, as opposed to arithmetic, began. If you had asked an ancient Sumerian, living in what is now Iraq, how big a field was, he would have answered "6 bushels", this being the amount of seed needed to sow it. After a while some bright man found that if two fields were rectangular, but one was twice as long as the other, and three times as broad, it would need six times as much seed. In such ways as this geometry began. But it took a long time before people measured fields in acres or other measures of area, instead of bushels, and discovered how to find the area of a field by linear measurements with a cord or a chain.

For thousands of years mathematics remained a mere collection of rules, even if they were very complicated rules for predicting the position of the stars. No-one seems to have tried to show that these rules must be so, any more than we try today to show that all animals with backbones must have red blood, or that the earth must have only one moon. Then the Greek philosopher Thales made a great discovery. He showed not only that the angle in a semicircle was a right angle, but that this must be so. That is to say if you join the two ends of a semicircle to any point on it, the two lines must always make a right angle. Starting from this discovery the Greeks produced a science of geometry in which most complicated properties of figures made of straight lines, circles, and a few other curves, could be proved, starting from a few simple laws which were taken for granted.

This was a great advance, but it was a one-sided advance, for it made them despise any scientific truth which could not be proved in this way. This scorn arose from a contempt for manual labour which was inevitable in a master class where all the hard work was done by slaves. And so the ancient world made little technical progress, and did not get far in those branches of science, that is to say all branches but mathematics, where technical means, such as telescopes, microscopes, accurate balances, thermometers, and so on, are needed. And their philosophies were generally idealistic. That is to say, they believed that thought came before things.

Then the slave civilization collapsed, and in the so-called dark ages little intellectual progress was made. But the workers gained a great deal of freedom, and during this period such great inventions as the horse-shoe, horse collar, windmill, clock, and rudder were made.

When mathematical progress began again, it was still on the Greek lines. Everything had to be proved from first principles. Only a century ago the first calculating machines were made which really saved an appreciable amount of human labour. At first they were simple, and did not involve any principles beyond complicated systems of cog-wheels. But later on electrical as well as mechanical methods were employed. Using such methods we can solve problems in a few minutes, which would have taken many days on paper. For example we can find the answer to twelve simultaneous equations.

For a long time the "pure" mathematicians despised such machines, saying that they were only good for engineering problems. But there are no "purer" problems than the properties of whole numbers. And one of the latest of these machines will find the factors of very large numbers, which is no joke to do by ordinary methods. For example if you want to find out whether 10379 has any factors, it is enough to divide it by every prime number up to 101, its approximate square root, that is to say by 2, 3, 5, 7, 11, and so on. But if we try this on a number of 21 figures, we may have to divide it by every prime number up to ten thousand million; and there are several hundred million of them. Yet the machine in question, which includes a photo-electric cell, will give the answer in a few minutes.

Other machines solve much more practical problems, for example the problem of how best to regulate the temperature of a furnace, or the course of an aeroplane flying blind, so as to give the quickest possible return to normal after a deviation, without oscillations round the correct temperature or course. This particular machine will also do work corresponding to many months' calculation in a few minutes. This entails somewhat of a revolution in mathematics, which seems destined to become more like the other sciences, and less based on "pure reason", which of course is a fiction, because you can't reason about nothing.

In fact mathematics is coming more and more to rely on instruments, as the other sciences do, and is being liberated from the extreme idealism which it inherited from the Greek slave-owners. Among other things this will probably mean that children in future will have a good deal less mathematics to learn by heart, and will be able to make a great deal more use of them than today. So the anti-aircraft predictor may be a step towards the goal of making mathematics the servant of humanity, instead of a source of puzzles for professors and dreary homework for children.

Measuring Time

WHEN we use such an expression as "the progress of science" we are apt to think, on the one hand, of inventions such as the electric motor, the microscope, or the aeroplane, or of theories such as the theory of gravitation, of chemical atoms, or of evolution. But besides these qualitative steps, we may roughly gauge the progress of science by the accuracy of measurements. Every skilled worker knows that these determine the accuracy and efficiency of craftsmanship to a large extent. But they also determine the progress of scientific theory. A theory which has been good enough for some centuries may at once turn out to be inadequate when the accuracy of a measurement is increased a hundred times.

A historical survey of some kinds of accuracy is given by H. T. Pledge in his historical work *Science since 1500*,[1] a book written for scientists rather than the general public, but yet full of interest for skilled workers who want to understand how science developed. He devotes considerable attention to the measurement of time. Some unknown man or men of genius invented the sun-dial thousands of years ago, perhaps in Egypt. This enables the time to be read within ten minutes or so, and is very useful in countries where clouds are rare.

But in the cloudy countries of northern and central Europe the sun-dial might be useless for weeks on end. So the clock was invented during the Middle Ages, almost certainly by monks. This was an enormously important invention, for it led to such relatively complicated principles as that of gears. The early mediaeval clocks might gain or lose a quarter of an hour per day, and had constantly to be set by the sun-dial. And even at the end of the Middle Ages the best church clocks, some of which survive, might be out by five minutes in a day.

In 1657 the Dutchman Huyghens first used a pendulum to regulate a clock, and a few years later Hooke, in England, employed a spring like the hair-spring of a watch. As a result the error was cut down to about ten seconds per day. And now a great possibility opened up. The measurement of latitude is relatively easy. In principle one could calculate it most simply from the height of the pole star above the horizon, if the pole star were due north. Actually the method is more complicated, but it does not involve accurate knowledge of the time.

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[1] Stationery Office, 7s. 6d.

A similarly simple method of finding longitude would be to find out the time at which the sun was highest, provided one had a clock keeping a standard time. The actual method is again more complex. Now the earth turns through an angle of one degree in four minutes, so an error of only ten seconds of time would mean an error of one twenty-fourth of a degree in latitude. This is three miles at the equator, and rather less than two in the neighbourhood of England. But unfortunately in a voyage of several months the clock's error might mount up to hundreds of miles, so the early clocks were little use for navigation. However, within a century the accuracy was still further increased, mainly by compensating for the changes caused by temperature in the length of the pendulum or the elasticity of the spring.

In 1761 Harrison produced a chronometer which received a British Government prize, and played a big part in founding the British Empire. Its daily error was about a fifth of a second, so even after a month's voyage the error of distance was only about a mile. Greenwich mean time and the meridian of Greenwich became universal standards.

Measurement is economically necessary in the case of commodities, and just as wheat is measured in bushels, cloth in yards, and meat in pounds, so labour power is measured in hours. In the class struggles of the 19th century the length of the working day was one of the main questions. This was only possible because clocks which were accurate to a minute or so were fairly cheap by that time.

By 1900 the daily error had been reduced to a hundredth of a second by keeping the air pressure constant, and the modern Shortt clock, whose pendulum swings in a vacuum, is still more accurate, though no clock is yet correct to a thousandth of a second per day, or one part in 86,400,000.

But the best clocks are probably rather better time-keepers than the earth. The day must lengthen if the ice at the poles melts, and the resulting water flows towards the equator so that it has to move farther in a day, and therefore the earth slows down. It is at least possible that such changes are now being detected.

Pledge also gives figures for the accuracy of weighting. Numerous ancient weights and balances have been found, and in the dry climate of Egypt they are little corroded. So we can say that as early as 1000 B.C. the error in weighing had been reduced to 2 grains, which is good enough for most commodities except precious metals and drugs. The Romans reduced this to about half a grain. By the end of the Middle Ages it was a tenth. The modern chemical balance, with steel knife-edges on agate bearings, came in about 1825, and reduced the error to a hundredth of a grain. This is better than is needed for any economic purposes, except perhaps the weighing of gold. But it made modern chemistry possible. For Dalton's atomic theory was just being accepted, and it was necessary to determine the ratios of the weights of different atoms with great accuracy.

Towards the end of the 19th century another great step was taken. When the barometer is high, that is to say the air is denser than usual, a light substance such as glass appears to lose weight relative to a brass or platinum standard because it is buoyed up by the air, just as a pendulum swings more slowly. So by weighing in a vacuum the error was reduced to a thousandth of a grain. Since then there have been still further advances. One result of accurate weighing has been to prove that atomic weights were nothing definite, since most if not all elements are mixtures of different kinds of atoms with different weights. So just as the day is proving useless as an ultimate standard in time measurement, though it is the only possible practical standard, atomic weights have no absolute values, though every chemist uses them in practice.

This seems to be the general fate of scientific measurements.

People usually make them first for some economic reason. Then they prove to be of importance for settling scientific problems. But after a while they become meaningless because the standards are variable. Yet though completely accurate measurement is impossible, fairly accurate measurement is essential. In the last century we learned to measure things like electric currents whose very existence was unknown until the 18th century. Today psychologists are trying to measure mental abilities. The attempt has been largely made in response to a demand for psychological tests of suitability for jobs. The first rough tests proved unsatisfactory, and were biassed because the qualities characteristic of university professors were labelled "general intelligence". But if these difficulties are overcome, and real measurement becomes possible, psychology will take its place among the sciences.

A.R.P. Fallacies

TODAY every gossip column-writer in the capitalist press, and every minister, is pouring out soothing syrup concerning shelters. Some of it is obvious nonsense. *Reynolds News* tells us that someone in Whitehall has calculated that the chance of being killed in an air raid is only one in 8000. As much more than 5000 out of 40,000,000 English civilians have already been killed, this is as out of date as many other Whitehall calculations.

The *Evening Standard* tells us that every trench has a protective wall of earth thousands of miles thick. The plain fact is that a trench is less vulnerable than a surface shelter to the blast, or air wave, from a bomb bursting on the surface. But it is more vulnerable to the shock, or earth wave, from a bomb which buries itself before bursting. So unless you have private information from Goering as to which type of fuze will be used tonight, a sensitive one causing a burst on the surface, or a tougher one causing a burst below ground, there is little to choose between a brick shelter and a thinly lined trench.

But the worst fallacy is the fallacy of dispersal. Mr. Churchill, Mr. Morrison, and Miss Wilkinson, all say that this makes for safety. This is untrue, as any statistician will tell them. I published the relevant mathematical theory in *Nature*, our leading scientific weekly, two years ago, in the hope of obtaining criticism, but no-one challenged it. Since then Mr. Arup has developed it in much greater detail, using his engineering knowledge, which greatly exceeds my own. The effect of dispersal, provided the type of shelter remains unchanged, is that no single bomb will cause many casualties, but each bomb has a bigger chance of causing some. And these tendencies cancel one another out very exactly.

If you don't care for mathematical arguments, try this experiment. Divide a piece of paper into 400 squares by 21 lines ruled each way. Put a figure 2 in 40 of these squares.

[1] October 1940.

Then drop a small object, say a threepenny bit, a hundred times on the paper at random. If its centre falls on a square with a figure 2 in it, count 2 people as killed. You will probably "kill" a little less than 20 people. Accurately your expectation is 17·7, allowing for the chance of hitting the same square twice. Now put a figure 8 in 10 of the 400 squares, and drop your "bomb" a hundred times. Your average number of "casualties" will be just the same, but the fluctuations round it will be bigger.

This is an example of what is called a model experiment, which has proved very useful in science, though of course it may leave out something important. The main thing left out in this case is that if one bomb wounds 200 people, there will be a greater strain on the stretcher parties and hospitals than if it only wounded 20.

Behind the fallacy there is of course a truth. The truth is that any large shelter, unless it is completely bomb-proof, like the deeper parts of some—but by no means all—tube stations, is more dangerous than a small one. If I am in a cellar 10 feet square with a stout reinforced concrete wall round it, a medium-sized bomb must fall on the shelter or within 5 feet of it to kill me. That is to say the danger area is about 400 square feet. But if the shelter is 50 feet square, the danger area is about 3600 square feet, or nine times as great. That is to say I am nine times as likely to be killed. But I am no more likely to be killed if I am one of a hundred people in the shelter than if I am all alone.

The moral is not that people should be dispersed, but that shelters, unless they are really bombproof, should either be small, or divided up into small compartments by really blast-proof walls, not thin brick walls with very poor mortar between the bricks. I am certainly horrified at the large size of some of the non-bombproof shelters. The upper part of a tube station is often close below the ground, with only a foot or so of concrete above it. A bomb bursting inside is in an enclosed space, so the blast cannot escape, and may cause frightful damage. Yet some people think they get security in such places, or on escalators, which are only a little safer. I would much sooner be in a small brick surface shelter than an underground "shelter" of this kind during a raid. Indeed if I had a steel helmet I think I would as soon be in the open air. The deeper parts of tubes are of course much safer, provided they are protected from flooding, which is not always the case.

Why do so many people believe that dispersal makes for safety? Partly because they say that a bomb falling on a shelter containing two hundred people may kill them all. This is quite true, but it is an argument not against having more than half a dozen or so people in a shelter, but against using shelters with a large area, unless they are really bomb-proof.

The theory of probability is largely a history of the fallacies which have deceived quite able men in the past. Some people have thought that, because if a coin is tossed often enough, the number of heads and tails is roughly equal, this implies that after a run of, say five heads, there is an unusually big chance of a tail. This is certainly untrue. Others think that after five heads, there is a bigger chance of another head. This is true if the coin is biassed, and though I know of no thorough tests on coins, careful investigation of dice has shown that they are often biassed. One reason is that a face with six holes in it is rougher than one with one hole. The die is therefore more likely to turn over if it falls with the six downwards than with the one downwards. This causes a bias in favour of high scores. But this bias is generally very slight.

The corresponding fallacies about bombs are that a bomb is unlikely to hit the same house twice, or that it is very likely to do so. Once again the latter is more nearly true. For an airman aiming, say, at a station or a factory may make the same mistake on two different nights. But the extra probability is not worth worrying about.

Some people think you can come to no certainty about matters of probability. This is not so. The theory of probability is as exact as other branches of mathematics. But it takes longer to test. If we want to test the truth of the theorems that $15 \times 14 = 6 \times 35$, or that all the angles of an equilateral triangle are equal, we can easily do so, though only roughly in the latter case. To test a theorem in probability we might have to spin a coin ten thousand times. Nevertheless I think probability theory should be taught in school. Perhaps when stocks and shares and compound interest are out of date we shall find time for it. Till then I fear that people may go on believing such statements as those of Messrs. Churchill and Morrison on dispersal.

Samples

SAMPLING has recently become important in two contexts. In the first place a small sample is taken from a large number of mass-produced articles, and the articles in the sample are tested, often to destruction. Secondly, samples of the population are taken. The Gallup Poll agents, or the Ministry of Information employees, ask their political views; or workers for the Ministry of Food find out how they spend their points.

Is this a reliable and scientific proceeding? The answer is that everything depends on getting a really random sample. This is fairly easy in the case of bolts or screws. One can take care that they were not all produced from a particular piece of steel or by one machine. In agricultural research very special care is taken to get a random sample. Suppose we are testing five varieties of potato on soil which has been manured in four different ways, it will be desirable to grow each of the twenty possible combinations on four or five different plots scattered about a field. If the same variety with the same manure gives very different results in different places, we cannot conclude much about the value of the manuring or the potato breeds.

If your sample is really at random you can reach conclusions of great certainty about the population or other large group from which it is taken. If 22 out of 100 turnips are diseased, there is only about one chance in twenty that more than 30 per cent or less than 14 per cent of the batch from which the sample is taken will be diseased. If we took a larger sample, the limits would be closer together. This theory of sampling is important in anthropology. We measure, say 20 skulls on one island and 35 on another, and find a difference in the averages. Can we conclude with fair certainty, that, owing to race or environment, we should find a similar difference if we measured hundreds? This is the sort of question which a professor of biometry like myself has to answer.

The success of sampling in many scientific fields led to attempts to apply it in politics and economics. But here we have to be very careful. Suppose we took a really random sample of 100 voters in a constituency, and 70 supported the present member of parliament, there is only about once chance in 50,000 that he would be defeated in an election, if all the constituents voted. But how are we to be sure the sample is really random? If the investigation had mixed up all the voters' names in a box, pulled out the first hundred, and hunted them down, we should really have a random sample. But this is never done. In practice some people are harder to find than others. Perhaps they are Labour voters working overtime, perhaps Tories away for the week-end.

This is one difficulty. Another is that, even where secrecy is observed, some people do not believe it. Certainly they are more likely to lie about politics than about points. Finally, experimental tests have shown that the way a question is framed makes a great difference to the number of people who answer it in the affirmative.

The ancient Greek democracies, such as Athens, chose many of their officials by lot, for a period of a year. They were, in fact, a random sample of the citizens. This system could only work where, as at Athens, every citizen had to attend the public assembly from time to time, and was fined if he did not. Similarly in the Soviet Union today all citizens get at least some political education from attending public meetings to decide on local as well as national affairs. But they do not get jobs by lot.

In Britain criminals are tried by a jury which is supposed to be a random sample of their adult fellow-citizens. Unfortunately this is not the case. The list of jurymen is considerably biassed in favour of the well-to-do. The situation is still worse regarding libel actions where a large sum of money is involved. These are tried before a special jury composed of men and women with very substantial property qualifications. It is unusual ror a special jury to include even one trade unionist. The injustice of this is obvious when, for example, a rich man sues a working-class newspaper for libel, though it may have been reasonable when most people could not read. A democratization of our jury system should be part of the programme of all democrats.

Statistics

STATISTICS is the branch of science, or perhaps of applied mathematics, dealing with large numbers of individuals. Originally the word meant the compiling of numbers about the state, for example censuses of population, production, and so on. Today it is applied to many other fields.

For example biologists use statistical methods. They shoot birds and count the numbers of various kinds of insects which they have eaten. They compare the average yields of different kinds of wheat, and the effect on them of rainfall, fertilizers, time of sowing, and other influences.

Modern physics is largely based on statistical mechanics. A liquid consists of millions of molecules in rapid motion. Any one of them near the surface may pick up extra speed as the result of collisions with its neighbours and fly away as vapour. One can make no prediction about a particular molecule. But one can predict very accurately what fraction of a large number will fly off in the next minute.

Astronomers also use statistics, because by now so many stars have been photographed that it is a hopeless task to catalogue them all. But we can count their frequency in different directions, compare the average speeds at which different kinds are moving, and so on.

There are two essentially different kinds of statistics, namely those based on a complete investigation of a group, and those based on a sample. Government statistics are generally supposed to be of the first kind. For example the census (which by the way ought to be taken in 1941, but will not be) is supposed to cover the whole British population, and probably does not miss one in ten thousand.

But statistics of this kind are often inaccurate. In some countries more births of girls than of boys have been registered because boys were reported as girls to avoid military service. British figures of unearned income are too low because, for example, a capitalist can invest in a new insurance company, drawing no dividend for some years, but be fairly sure that the shares will increase substantially in value. If he later sells out, he can pocket the profits without paying tax .

One might think, however, that it was always better to investigate a whole population than a sample. This is not necessarily so. Some official statistics are very dubious, notably the causes of death which are registered. A doctor sees that a man or woman is ill, does his best to diagnose the disease, and if they die, fills in a form accordingly.

Even the best doctors, with X-rays, bacteriological laboratories, and other such facilities, make some mistakes. The average doctor, with no such help, makes many more. This is probably specially so with young babies and old people.

Old people commonly have weak hearts, and whatever is the ultimate cause of their death, their hearts will often fail sufficiently to justify a doctor in ascribing their death to heart failure. Others die of pneumonia though the organ which first failed is not the lung.

If I were dictator (which heaven forbid) one of the reasons for my unpopularity, and I hope, for my violent removal, would be that I should insist on post-mortem examinations being made of everyone who died during a period of, say, a month. If I did, they would very likely be faked, as many things are under dictatorships, but we should perhaps gain more knowledge of the true causes of death.

For many purposes we can only study samples. For example a few towns have been studied intensively to find out what people actually eat, and from them rough calculations have been made to determine what fraction of the whole people are undernourished.

In the same way numbers of people have been carefully weighed, measured, and tested for colour-blindness, membership of different blood groups, and so on. If the set tested has really been chosen at random, we can calculate with great accuracy to the numbers in the whole population.

For example if out of 10,000 men tested, 250 were colour-blind, then the odds are several hundred to one that in a population of a million the number of colour-blind men will be between 20,000 and 30,000, provided the first sample was taken at random.

But it may not have been a random sample. A large number were tested at an exhibition, but perhaps men who suspected they were colour-blind took the test more frequently than normal men. Or perhaps normal men took it, and colour-blind men did not, for fear of looking silly.

Such a test is only valid when it is done on a group selected in some other way, for example on all the children in a group of schools. And of course no amount of care in selecting your sample at random will get over other kinds of bias.

The Ministry of Information collects data on public opinion. Various people are asked their opinion on political questions, and are told that their names will be kept secret, and only total numbers given. Now I personally believe that this promise is kept. But it does not follow that the people who are asked the questions believe it too.

If they don't, some of them will give the answers which they think will please the Government. And so if more people say that they approve of official policies in January than in December, this may mean that the public is getting fonder of Churchill or more frightened of official spying. And there is no way of finding out which explanation is true.

Inquiries of this kind can hardly claim to be scientific. Observations of actual behaviour can. A comparison of the number of people who go to un-reinforced brick surface shelters as compared with basements or trenches would tell a very clear story of the small confidence which they inspire. Lenin was talking scientifically when he spoke about people voting with their feet.

In agricultural experiments great care is taken to avoid bias. Thus if you are testing three kinds of wheat in a field, it is useless to divide the field into three strips of equal area. One may be drier than others, or have better soil. The field must be divided into about thirty plots of equal area, ten sown with each kind of wheat.

It will probably be found that owing to differences in the soil, one or two plots of the best wheat will yield less than some of those of a poorer variety. There are, however, mathematical tests which allow one to say whether the observed higher yield of one kind of wheat over the others means anything, or is due to chance.

Unfortunately tests of this sort are rather rarely applied in official statistics. That is one reason why people say that you can prove anything by statistics. Actually you can prove a good deal. But it needs a lot of training to avoid pitfalls. In a later article I shall write about some of the methods which scientific statisticians use.

More About Statistics

SCIENTISTS aim, so far as possible, at clear-cut experiments. A plant is grown in a solution of various minerals, including iron salts, and is healthy. The iron salts are left out; the leaves of a similar plant are yellow, and it dies. A sufficiently strong electric current always acts on a compass in its neighbourhood, a man always loses consciousness if he breathes nitrogen, and so on. But very often this cannot be done. Sometimes experiment is impossible. You can't do experimental astronomy. And an experimental study of human heredity is impossible in practice. Sometimes the experiment is not clear-cut. For only some, but not all, of the variation in the result is due to the experiment, and the remainder cannot be eliminated.

Here the statistician comes in. He may be asked two questions. The first is whether the experiment has had any effect at all. Suppose five rats fed on one diet weigh 6·5, 6·8, 6·9, 7·2, and 7·5 ounces and five similar ones fed on another diet weigh 7·1, 7·4, 7·7, 7·9, and 8·3 ounces (of course in scientific work grams would be used for weighing). Can we be sure that the diet has had an effect on the weight?

No, we can never be absolutely sure. But we can be quite sure enough for practical purposes. The statistician does not ask the question in this form. He asks what is the chance that two groups as different as these should have been picked out of the same population by mere luck. The statistical method for answering this question was devised by the late Mr. W. S. Gossett, who was employed by Messrs. Guinness, the brewers. The firm did not permit its employees to publish work under their own names, so he signed his papers "Student", and many statisticians only learned his name when he died. In the particular case of the rats, the odds are about 40 to 1 against the difference between the two groups being due to chance. A good biologist would be fairly sure that the difference was due to the food, but he would repeat the experiment once or twice before publishing his result.

A second question asked of statisticians is "How much of the variation in one quantity is determined by variation in another?" In the above case only some of the variation was due to the diet, because there was still a good deal of variation among rats on the same diet.

Human height is to some extent hereditary, though it also depends on diet, and probably on climate and other factors at present unknown. Suppose we measure a thousand boys of the same age, and their parents, we ask what is the difference between the average height of a group of boys whose fathers are 5 feet 6 inches high and of a group whose fathers are 5 feet 10 inches high. The answer is "about one inch". An increase of an inch in the father's height means an average increase of about a quarter of an inch in the sons. The mother's influence is about the same. The degree of resemblance is measured by a number called the coefficient of correlation which, for parents and children, is about a half.

It is one thing to state a statistical result, and quite another to interpret it. The first statisticians who measured resemblances between parents and children put them down wholly to heredity. This is correct in some cases, particularly when the people concerned are taken from one class of a particular nation. For example there was probably little malnutrition among students of Oxford University in 1900.

But it is certainly untrue in other cases. The Japanese mostly have slanting eyes when compared with Europeans. They are also shorter. Both are often thought to be racial characters determined by heredity. If a Japanese couple emigrate, their children still have slanting eyes, so the eye shape may be regarded as a racial character fixed by heredity. But their average stature may be greatly increased, as Suski found after measuring some hundreds. The average height of Japanese boys of 15½ born in Japan is 5 feet 2·8 inches, of those born in America 5 feet 4·4 inches. The weight is increased from 99 pounds to 114 pounds. What is even more remarkable, the American-born Japanese at this age are slightly taller and heavier than American boys of European stock. This may be due to the fact that the whites lived in many different states, the Japanese mostly in California, where conditions seem to favour rapid growth. The few adult American-born Japanese measured averaged three inches taller than their parents.

Results like this make it rather hard to believe most of the stories of racial superiority and inferiority which are spread by conquerors, whether British or German. If a small fraction of the sum spent on the Chinese war had been devoted to feeding the people, the Japanese could probably be converted from a short to a tall race. Let us hope that a Japanese People's Government may soon try this interesting experiment.

This example shows the value and the limitations of statistics. It is a common gibe that "you can prove anything by statistics". All that you can prove is some fact such as that the children of tall parents are generally taller than the average. To find out why this is so, you must experiment yourself, or take advantage of a natural or social experiment such as the transplanting of Japanese to California.

But if you can't prove much by statistics alone you can prove nothing at all in some fields without them. Among a thousand badly undernourished children a few will be taller and even stronger than the average. If they are picked out they can be used for a "sunshine story" about the adequacy of our food. The sunshine stories which we read in the press about shelters come into this category. We all know of cases where a house was destroyed and a shelter untouched. We also know of cases where the contrary happened. Only a statistical investigation could tell us which kinds of shelter are of any value. Such an investigation would have to be carefully done. If we merely compared the fraction of people sleeping in shelters who had been killed to the fraction sleeping in bed who had been killed, we should find that bedrooms were much safer than shelters. This would be unfair to the shelters, because few or no people sleep in shelters in country districts, while many do so in heavily bombed areas. For a fair comparison it would be necessary to compare bedrooms and shelters within a number of small districts, say within each of a hundred wards in different boroughs. I do not know what the result would be, though I think it would show that some kinds of shelter are worse than useless, whilst others give partial protection. Very inadequate surveys seem to show that the Anderson shelter cuts down the chance of death to about a quarter, while brick surface shelters without reinforcement are useless, as are many basements. If the Minister of Home Security has made an inquiry of this kind he should publish its results, if only to let people know which kind of shelter to choose. If he has not yet[1] made it, he should be replaced by someone who will apply scientific method to this vital problem.

These examples prove, I think, that statistical methods are indispensable. But they also show that they easily lead to false conclusions, and that everyone in the intellectual side of the Labour Movement should know something about the use and abuse of statistics.

[1] January 1941.

Millions

ON one page of a London evening paper I recently read the following two sentences. "The Geneva municipal council are pressing for a special tax on foreign bank deposits in Switzerland, which total about £3,500,000,000." "Almost £25,000,000,000 in uncommitted balances now held by the War and Navy Departments, the Maritime Commissions and the War Shipping Administration, will be investigated to see if the amount can be returned to the Treasury."

It is quite clear that the sub-editor who passed these items had little idea of what a million means. The Nazi leaders may have banked a lot in Switzerland, as the headline to the paragraph suggested, but the sum mentioned is about the value of the total annual production of England before the war. International payments on this scale are impossible. The sum is more than half what Germany was supposed to pay in reparations after the first world war. As for £25,000,000,000 even although it is the American, not the British Treasury, this amounts to about £150 for each American citizen, and the return of it to the Treasury would nearly make the war profitable!

Some readers will say they can't imagine a million. This is untrue. You can't imagine a million things in a row very easily, though a million halfpennies would only stretch less than 16 miles, which is an easy day's walk. You can easily imagine a million in a square, for example a square metre of paper ruled in millimetres. And you can very easily imagine a million cubes, say lumps of sugar, arranged in a large cube with a hundred in each side.

Now scientists have to think in millions, and to get the feel of them, so to say. When the millions are arranged in a line this is rather hard. For example light travels about a million times as fast as sound, sound about a million times as fast as the second hand of a watch, and the second hand about 200,000 times as quickly as a human body grows.

When the millions are arranged in a lump, the thinking is often fairly easy. For example a human body contains something over 10^{16}, or 10,000,000,000,000,000 cells. This seems a hopeless number to grasp, but it is quite easy when you think of it concretely. All these cells arise from one single cell. This cell divides in two, and so does each of the new cells. That is to say after 1 division there are 2 cells, after 2 divisions 4, and so on. It would take only 47 divisions to produce all the cells of the body, and a representative cell has about 50 generations behind it, though some have more, and some less. For a small insect the corresponding number is about 25.

A scientist is constantly thinking in such numbers, not because he is interested in how many matches laid end on end would reach to the moon, but because he may have to work with a ton of matter one day and a milligram the next; and there are a thousand million milligrams in a ton.

Anyone who is going to take economics seriously must learn to think in millions, because the population of states are reckoned in millions. Incidentally such numbers of living beings can never be quite accurate, not because they are uncountable, but because at any moment some are being born and some dying; and neither process is instantaneous. You must be dialectical about large numbers.

One of the first things you must do in order to understand economics on a national scale is to get the habit of translating backwards and forwards from millions to sixpences. There are 40 million people in England, so sixpence for each of us is a million pounds. For example the war costs about ten million pounds a day. This means that Mr. Chamberlain's political opinions cost each of us five shillings a day on an average. It also means that if the productive forces engaged in war were switched over to the needs of peace, there would be five shillings a day per head to be shared out, or over ten shillings a day per wage-earner. Again when a man receives a legacy of a million pounds, this means that, by allowing such a monstrous transaction, every man, woman, and child in Britain is, on an average, giving him sixpence.

It is worth while getting this habit with millions of pounds, because the opponents of such necessary measures as the Beveridge scheme will try to frighten us with its vast cost, and a figure of hundreds of millions of pounds sounds impressive.

Any student of science can get a grip on these big numbers by making a guess a day involving them, and then checking up. For example, roughly how many safety-razor blades could one make out of the *King George V?* An acre of English ploughland contains about 800,000 earthworms; how many are there in England? How far does the hour-hand of a watch go in a century? If one part in a million of the earth's crust consists of gold, how many tons of gold are there in the first ten miles for each member of the human race? (about 40!).

Only after you have done this, and got happy with millions, is it any good trying to grasp the large numbers which occur in physics and chemistry, such as the number of atoms in a gram of hydrogen, which is 6×10^{23}, or nearly a million million million million. But millions are not really difficult to deal with, and to learn to do so is an essential part of education.

Infinity

SCIENTISTS are not directly concerned with infinity, because we have no experience of infinite things, times or numbers. But scientists use mathematical methods which involve the use of infinity, so they are quite familiar with the idea. What is more curious, they find it makes their work easier.

Let us see why. Take the series $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+$ etc. We can see that the sum of two terms is $\frac{3}{4}$, of three $\frac{7}{8}$, and so on. That is to say at each step we halve the difference from one. We say roughly that the sum of an infinite number of terms (or of all the terms) is one, and accurately that by taking enough terms we can reduce the difference from one to be as small a number as we choose. If I ask you for the sum of a million terms you will never be able to write down the answer, for it is a fraction whose numerator and denominator each have 301,031 figures. That is to say either would cover a whole issue of a newspaper, even if printed rather small. So we simplify matters vastly by taking an infinite number of terms instead of a very large number.

Mathematicians have used infinite series for a long time, and without them they could not calculate such universally useful numbers as common logarithms. But they only used them as a result of breaking the rules which had been laid down by former mathematicians. This indeed is one of the ways in which mathematics progresses. Two thousand years ago every mathematician, except perhaps in India, would have agreed that the sum of two numbers was larger than either of them. Then some Indian genius invented a sign for zero, which made it possible to write every number with only ten signs. But it also meant that if you added zero to a number it got no bigger.

Later still, negative numbers were invented, and still more rules were broken. This is a dialectical process, as Marx and Engels pointed out. And now mathematicians deal quite happily with infinite numbers. Let us see what an infinite number means.

If we say that the number of whole numbers such as 1, 2, 3, 4, is infinite, we mean that this series has not got a last member. If somebody said that a trillion was the largest number, we could answer that a trillion and one is larger. In fact an infinite number is the expression of a possibility, the possibility of always adding one more. But it is not the expression of a fact about nature. We can never prove by observation that space is infinite, or that the number of atoms in the universe is infinite. Some day it may be possible to prove that this number is finite, though this seems to me rather unlikely.

Engels wrote about "bad infinity", by which he meant a mere absence of determination. And the word "infinity" is, of course, used very loosely, especially in connection with religion. Let us see how it can be used exactly, how for example, we can say that two infinite numbers are equal, or that one is greater than another.

There are two ways of finding out whether the numbers in two groups are equal. We can count both of them, or we can arrange that each member of one should correspond to one and only one member of the other. For example, if I am addressing a public meeting and want to know whether there are more seats or people in the audience, I don't have to count either people or seats. If there are a lot of vacant chairs I know there are more chairs than people. If there are a lot of people standing I know there are more people than chairs. In fact this is how audiences are roughly counted by reporters, who know the number of seats.

Now we cannot count an infinite set, but we can compare two infinite sets in this simple way. For example the number of even numbers is the same as the number of all whole numbers, even or odd. For we can call 1, 2, 3, 4, etc. the audience, and 2, 4, 6, 8, etc. the chairs. We then put 1 on 2, 2 on 4, 3 on 6, and so on. In this case every member of the audience gets a chair, and every chair a member, so the numbers are equal. This means that some infinite numbers are equal to twice themselves, which need not, of course, surprise us. We can't expect all the ordinary rules of arithmetic to hold for infinite numbers. But it does not mean that all infinite numbers are equal. On the contrary, it can be shown that whatever system is tried of labelling all the points in a line with whole numbers, there will be some points left over. That is to say the number of points in a line is greater than that of whole numbers. And plenty of still larger infinite numbers are known.

Someone may well object that calculations of this kind are mere jugglery with words and symbols, and have no relation to reality. The answer is simple. The theory had to be made to meet a practical need. If we have a record such as that of the height of the sea water at Liverpool over many years, we can analyse it into a series of waves. For example the tides show a principal wave with a period of about twelve and a half hours, another with a period of about a fortnight, and so on. The theory of disentangling these waves is a very difficult one, but a very practical one too. It comes up again in connection with the oscillations of a suspension bridge or a steel-frame building, or the interpretation of the X-ray photograph of a crystal. And no-one was able to work it out until the theory of infinite numbers had been developed.

Even now mistakes are often made. The designer of the great suspension bridge at Tacoma, in the state of Washington seems to have made one, for the bridge swayed so violently in the wind that it broke in two. And the theory is not complete. There are still contradictions. Indeed if a perfect mathematical theory could be developed, that would be the end of mathematics.

Most of the great unsolved problems of mathematics contain the word "all". For example thousands of maps have been drawn, divided into areas like counties, each of which has a single boundary, that is to say one can move all over it without crossing another "county". Each of these maps can be coloured with four colours only, so that no two colours touch, though they may meet at a point. But no-one has proved that this is possible for all maps.

The word "all" means one thing when it is applied to a finite collection, such as all the maps in the world, or all whole numbers less than a million. And it means something very different when it is applied to an infinite collection, such as all possible maps, or all whole numbers.

Nevertheless mathematicians have gone a long way in their analysis of infinity, and can already reason about it with far more accuracy than a century, or even twenty years, ago.

The Differential Calculus

NO elementary school child gets a chance of learning the differential calculus, and very few secondary school children do so. Yet I know from my own experience that children of twelve can learn it. As it is a mathematical tool used in most branches of science, this forms a bar between the workers and many kinds of scientific knowledge. I have no intention of teaching the calculus, but it is quite easy to explain what it is about, particularly to skilled workers. For a very large number of skilled workers use it in practice without knowing that they are doing so.

The differential calculus is concerned with rates of change. In practical life we constantly come across pairs of quantities which are related, so that after both have been measured, when we know one, we know the other. Thus if we know the distance along a road from a fixed point we can find the height above sea level from a map with contours. If we know the time of day we can determine the air temperature on any particular day from a record of a thermometer made on that day. In such cases we often want to know the rate of change of one relative to the other.

If x and y are the two quantities, then the rate of change of y relative to x is written $\frac{dy}{dx}$. For example if x is the distance of a point on a railway from London, measured in feet, and y the height above sea level, $\frac{dy}{dx}$ is the gradient of the railway. If the height y increases by 1 foot while the distance x increases by 172 feet, the average value of $\frac{dy}{dx}$ is $\frac{1}{172}$. We say that the gradient is 1 in 172. If x is the time measured in hours and fractions of an hour, and y the number of miles gone, then $\frac{dy}{dx}$ is the speed in miles per hour. Of course the rate of change may be zero, as on a level road, and negative when the height is diminishing as the distance x increases.

To take two more examples, if x is the temperature, and y the length of a metal bar, $\frac{dy}{dx} \div y$ is the coefficient of expansion, that is to say the proportionate increase in length per degree. And if x is the price of a commodity, and y the amount bought per day, then $\frac{-dy}{dx}$ is called the elasticity of demand.

For example people must buy bread, but can cut down on jam, so the demand for jam is more elastic than that for bread. This notion of elasticity is very important in the academic economics taught in our universities. Professors say that Marxism is out of date because Marx did not calculate such things. This would be a serious criticism if the economic "laws" of 1900 were eternal truths. Of course Marx saw that they were nothing of the kind, and "elasticity of demand" is out of date in England today for the very good reason that most commodities are controlled or rationed.

The mathematical part of the calculus is the art of calculating $\frac{dy}{dx}$ if y has some mathematical relation to x, for example is equal to its square or logarithm. The rules have to be learned like those for the area and volume of geometrical figures, and have the same sort of value. No area is absolutely square, and no volume is absolutely cylindrical. But there are things in real life like enough to squares and cylinders to make the rules about them worth learning. So with the calculus. It is not exactly true that the speed of a falling body is proportional to the time it has been falling. But this is close enough to the truth for many purposes.

The differential calculus goes a lot further. Think of a bus going up a hill which gradually gets steeper. If x is the horizontal distance, and y the height, this means that the slope $\frac{dy}{dx}$ is increasing. The rate of change of $\frac{dy}{dx}$ with regard to y is written $\frac{d^2y}{dx^2}$. In this case it gives a measure of the curvature of the road surface. In the same way if x is time and y distance, $\frac{d^2y}{dx^2}$ is the rate of change of speed with time, or acceleration. This is a quantity which good drivers can estimate pretty well, though they do not know they are using the basic ideas of the differential calculus.

If one quantity depends on several others, the differential calculus shows us how to measure this dependence. Thus the pressure of a gas varies with the temperature and the volume. Both temperature and volume vary during the stroke of a cylinder of a steam or petrol engine, and the calculus is needed for an accurate theory of their action.

Finally, the calculus is a fascinating study for its own sake. In February 1917 I was one of a row of wounded officers lying on stretchers on a steamer going down the river Tigris in Mesopotamia. I was reading a mathematical book on vectors, the man next me was reading one on the calculus. As antidotes to pain we preferred them to novels. Some parts of mathematics are beautiful, like good verse or painting. The calculus is beautiful, but not because it is a product of "pure thought". It is not a product of pure thought. It was invented as a tool to help men to calculate the movements of stars and cannon balls. It has the beauty of a really efficient machine.

To judge from the technical books which sell by tens of thousands in the Soviet Union, a bigger fraction of the people understand it there than here. In a society where workers are encouraged to understand their work it is natural that it should be widely studied. Those who are working to build such a society in our own country, even if they cannot yet learn it, should know a little of what it means.

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LOGIC

Logic

A READER asks me to write on elementary logic. "Logic" is derived from the Greek "logos", a word, and originally meant the art of using words accurately, so that an inference based on them is valid. It is now applied to the use of other symbols besides words.

Of course words can, and sometimes should, be used illogically. Shakespeare was justified in writing of "Books in the running brooks, sermons in stones," though "Stones in the running brooks, sermons in books," would have been more logical. But we must be very careful in switching over from one use of words to the other.

Logic was founded by the ancient Greeks, and systematized by Aristotle. The mediaeval philosophers merely developed Aristotle's ideas, but in the last one hundred and fifty years logic has grown along several new lines. These include dialectical logic, developed by Hegel, Marx, Engels and others, symbolic logic, developed by Boole, Peano, Russell, Whitehead, and many living men, and the logic of probability, developed by Laplace and other mathematicians. These different branches are not really distinct.

The traditional logic has its uses and its dangers. Its greatest use is to teach the accurate use of words. For example I do not believe that the Jewish law is divinely inspired and should be obeyed in all cases. If the word "Jew" means a man or woman who believes this, I want to see fewer Jews.

This does not mean that I am anti-semitic. I think people of Jewish origin have every right to be proud of a law which, about 3000 years ago, included the text "Thou shalt not deliver unto his master the servant which is escaped from his master unto thee" (Deuteronomy 24, 65), and to use this pride to help them to work for human liberation. If that is what "Jew" means, I wish there were more Jews. Unfortunately both Jews and Gentiles use the word "Jew" in both these senses in the same argument, and this leads to misunderstanding, and worse.

The danger of formal logic is that it leads us to believe that classifications are sharp, either in space or time. Our law is based on formal logic. A jury has to say that a man is either guilty or not guilty of a crime. In practice everyone knows that there are degrees of guilt; but a jury cannot assess them, and in consequence injustice is done.

Similarly one can generally count the people in a room accurately, but no-one could count the population of London accurately, because at any moment some are being born and others dying; and neither birth nor death is instantaneous.

Formal logic is concerned with relations which can be expressed by predication, for example "Montgomery is a field-marshal", "No women are field-marshals", from which we can deduce that Montgomery is not a woman. It helps us to avoid fallacious arguments, for example "Fifty Welshmen were convicted of theft, therefore Welshmen are thieves" (meaning that all Welshmen are thieves).

Symbolic logic, which uses symbols rather like those of algebra, deal with other relations, and classifies them. For example, if A is like B, then B is like A. Such relations are called reflexive. If A is larger than B, and B larger than C, then A is larger than C. Such relations are called transitive. Symbolic logic has proved valuable in laying the foundations of mathematics.

The logic of probability is nearer to real life. When I say "If I get to the station by 7.20 I shall be in time for work", I mean that I am so likely to be in time that I can take the chance. In the long run, the logic is quantitative. It is sensible to run a risk of one in a thousand of losing the train in order to finish breakfast, and foolish to take a chance of one in a thousand of losing one's life for the same reason.

If I run a risk of one in a thousand of losing my train (or my life) every day, I am rather more likely than not to lose it in 693 days. This kind of logic is very important, not only for states and large businesses, but for the foundations of science, where chemists and physicists deal with millions of atoms, and biologists with millions of cells, or of animals or plants.

Dialectical logic is specially concerned with change. Words, and the ideas for which they stand, change their meanings. So do the things and processes which they symbolize. Hegel saw that the laws of change were similar, as they must be if ideas and words correspond to reality.

But, as Marx put it, he stood on his head, by thinking that ideas determined reality, instead of the other way round. However, as ideas are simpler than the reality for which they stand, it is easier to see how they change, and hence the word "dialectical", which applies to Marx's theory of the world, is taken over from logic.

A good way of understanding what a word means is to argue about it. Smith says that man has a natural right to property. Jones says that property is theft. If each tries to understand the other, they will see that a man's claim to own his socks is more reasonable than his claim to own a hundred square miles of land. Smith and Jones are both right up to a point. This method of getting at the truth is called the dialectical method. The word comes from the same root as "dialogue".

Just the same is true of a real thing. Everything that exists has both permanence and transience. A boot is more permanent than a lightning flash, and less so than a mountain. But nothing is instantaneous or lasts for ever. Similarly the boot would be no good if it were as hard as iron or as soft as putty.

Further, ideas change because they involve internal contradictions. Our word "just" is derived from the Latin "jus", meaning law, and originally meant "according to law". Obedience to laws which can be altered by the state is a great advance on obedience either to impulse or to traditions which are thought to be unalterable. But after men had got accustomed to obeying law, they began to see that justice went beyond the law, and that a law could be unjust. The idea of justice had developed so as to negate its original meaning.

The same kind of thing happens in nature. An egg cannot stay put. It must either die or develop into a bird. A river cannot stay put. It removes soil and rocks in some places, and deposits them in others. The egg and the river develop by negating themselves. Dialectical logic should help us in two ways. It should teach us when to use ordinary logic, and argue about a thing as if it were unchangeable, and when to beware of the fallacies into which this leads us. And, what is more important, it should teach us to understand the process of change, and thus to adapt ourselves to a rapidly changing world.

But just as we must learn ordinary mechanics before we can understand the theory of relativity, and English grammar before we can go on to comparative philology, it is well worth learning a little traditional logic provided we do not take it too seriously.

Induction and Deduction

A WELSH comrade has asked me what I think about the relative importance of induction and deduction in science. He notes that Engels was convinced of the importance of deductive reasoning, and rather contemptuous of induction, at any rate as practised in his time.

By deduction is meant reasoning from general principles to particular examples. For example if we want an aeroplane to go 10 per cent faster, and the resistance varies with the square of the speed, we calculate that we shall need about 21 per cent more engine power. If a man has lost sensation in the skin of a symmetrical area on his buttocks, we deduce that he has had an injury to the last pair but one of sensory nerves entering the spinal column, or to the spinal marrow in this neighbourhood.

Induction means arriving at general principles from a number of examples. The rule that resistance varies with the square of the speed is only true over a certain range of speeds, and both the law and the range over which it holds were discovered by experiment. And the effects of various injuries to the nerves have been discovered by observing the effects of wounds and diseases.

In mathematics deduction is much more important than induction. Mathematicians try to prove all their results from simple principles. But at any given time there are always a few results which are well established, but not proved.

For example some whole numbers are prime, that is to say they have no factors larger than one. It is easy to prove that there is no largest prime number. On the other hand it is fairly sure that there is no largest pair of consecutive odd numbers both of which are prime, such as 191 and 193. But no-one has been able to prove it.

In physics deduction and induction are both important. Mathematical physics is a body of deductions from fairly simple assumptions. It works pretty well; but this is because when a simple set of assumptions will not work, a slightly less simple one is tried, and so on. For example, gases behave in many ways as if the moving molecules of which they are made had no size at all. If this were true Boyle's law would be exactly true. It is not exactly true, but it is quite true enough for a great many purposes. It is not out by 1 per cent over the whole range of pressures which men can stand, from a pilot eight miles above ground to a diver 500 feet under water. A more accurate law can be deduced if we suppose that the gas molecules are round elastic balls, attracting one another when they come close together. This again breaks down in the long run, but it allows much more accurate prediction of what actually happens.

In chemistry deduction is less important than in physics. A chemist has to learn immense numbers of hard facts for which there is no explanation. I do not mean that they are in any way miraculous or in the long run inexplicable. For example one can easily show, from the properties of the atoms concerned, why ice melts more easily than iron. But no-one can calculate the melting-points accurately from the atomic properties within ten degrees, let alone a hundredth of a degree. So chemists have had to find the melting-points of about a hundred thousand different substances. They can then frame inductive laws which enable them to guess the melting-points of new ones fairly accurately by analogy.

In biology there has been a vast amount of pure induction. We find a number of properties going together. For example all animals with backbones have red blood. We say that red blood is one of the characteristics of a vertebrate animal. Often however such inductions are not quite accurate. It is nearly true that all land vertebrates, or all four-footed animals, have lungs. But a few salamanders which spend most of their life on land manage to get on without them, and breathe through their skins. Similarly almost all hairy four-footed animals bring forth their young alive, but a few in Australia and New Guinea, such as the Platypus and Echidna, lay eggs.

These examples show the danger of inductions not supported by any deductive explanations. Aristotle tried to introduce deductive reasoning into biology, but without much success. Galileo succeeded. He applied elementary engineering principles to animals. If two animals are of the same shape, but one is ten times as big as the other in every direction, then its weight is a thousand times greater, but the cross section of its legs is only a hundred times greater. So each square inch must bear ten times the weight. That is why a daddy-long-legs as big as a cat would break its legs at every step, and therefore does not exist.

Later on other biologists made similar deductions as knowledge of physics and chemistry grew. But Darwin was the first to apply deduction successfully to the fundamental problems of biology. Others had been driven to a belief in some sort of evolution by the study of fossils, but Darwin showed why evolution was an inevitable consequence of variation, heredity, and the struggle for life. In this century genetics, the branch of biology concerned with inheritance and variation, has grown up, and embodies a good deal of deductive reasoning. In many cases one can calculate beforehand what kinds of offspring are expected from a given mating, and in what proportions, even when such a mating has never been made before. But in spite of this, deduction is not yet so important as induction in biology.

In the social sciences, most non-Marxists say that deductive reasoning is of little or no value: one can merely describe historical events, and cannot hope to understand them. Marx believed that one could use deductive reasoning, and he had the courage of his convictions, for he predicted what was going to happen in the future, which is the only real test of any scientific theory. Actually non-Marxists predict too. They tell you that the war will end in 1945, that there will be a Tory majority at the next election, and so on. As they do not believe that there is a science of history, these predictions presumably have no scientific or logical basis. So Marxists are more often right in their predictions.

But Marxist prediction is only valid if it is based on a profound knowledge of economic facts, which are difficult to ascertain, especially in war time. So Marxists should be careful of making detailed forecasts, though they can be sure enough of the general character of the social changes ahead of us.

What "Hot" Means

ONE reason why other people find it hard to understand science, and why scientists are apt to lose their tempers with other people, is that scientists either use ordinary words with a special meaning, or invent words of their own which ordinary people do not understand.

I don't think this can be avoided. The history of science shows what has constantly happened. We start with some ordinary word, such as "hot", whose meaning we think we understand. On the breakfast table are a tablecloth, a knife, and a pot of mustard. The plain man says the knife is cold, the mustard hot, and the cloth neither hot nor cold. A physicist will say that none of them is hotter than the others.

But that does not mean that the plain man is talking nonsense. He certainly gets a feeling of cold from the knife, and a feeling of heat from the mustard if he puts it on his tongue, or rubs it into his skin. The knife and the cloth are at the same temperature, somewhat below that of one's finger. But the knife conducts heat well, so it cools the finger much more than the cloth when one touches it.

The mustard, or to be accurate, one of the chemical compounds in it, excites the same nerve fibres in my tongue as are excited by hot substances, and gives me a sensation of heat. If I rub it into my skin it makes the blood vessels dilate, and my skin does actually get hotter in a way which a physicist could measure.

Until thermometers were invented and made fairly accurate, it was quite impossible to get any definite answer to the question which of two bodies was hotter, much less to measure temperature or heat. Even now we are apt to trust our senses unduly.

The woman who runs our household, in which I perform such humble functions as dish-drying, insists on putting food on a slate shelf rather than a wooden one in the larder, because it is colder. Actually everything put in the larder reaches the same temperature after half an hour or so. Warm things cool a little quicker on slate than on wood, and that is all the difference. If the food were like a living man or animal, and had a source of heat in it, it would be colder on slate than on wood. But if our housekeeper reads this, she will not believe the argument, and merely take it as another proof that men, and particularly professors, don't understand housekeeping.

Confusions like this arise in part because we use the same word "heat" for a sensation, and for a form of energy which causes it. We also use the word "hot" to mean either a body which gives us the sensation, or a body with an unusually large amount of this form of energy. Mustard is hot in the first sense, and not in the second. We should avoid these confusions if we used specially invented words such as "caloric" and "calorous" for "heat" and "hot" in their scientific senses. But when scientists use such words they are often accused of talking jargon; and such words are often taken over and used in a metaphorical sense. This is happening to the words "allergic" and "energy" at present.

Students of Marx find this difficulty with the word "value". In ordinary talk we use it in a good many different senses, and if we change its meaning in the middle of an argument we talk nonsense about economics. In *Capital* Marx first discussed some of its different meanings, and then used it with one particular meaning in the rest of the book.

The same was true of "labour" and "labour power". On the other hand he (or rather his translators) used the word "force" in a rather haphazard way, as compared with its very definite meaning in modern physics. He might have used some special word to distinguish between say productive force and electromotive force or gravitational force, but no-one is likely to confuse such very different meanings of the word "force", as they certainly confuse different meanings of "value".

An essential feature of the progress of science is as follows. We start with a word whose meaning we think we understand, such as iron, hot, rat, race, or intelligence, and begin to investigate the things which it designates. We always find that it changes its meaning in the course of the investigation, and sometimes we have to invent new words for the things we discover.

Iron is quite a good example. In ordinary language it is used for a variety of metals with different properties, particularly cast iron, which is hard but brittle, and wrought iron, which is softer but tougher. Chemists have found that they are all mixtures consisting largely of one metal. But the metal which chemists call iron is quite soft when pure, in fact about as soft as copper. Ordinary iron and steel are a great deal harder because they are intimate mixtures of iron and its compounds with carbon and other elements. In fact metallurgists use such words as austenite, martensite, and cementite to describe what is generally called iron or steel.

The ordinary word rat covers two different species in England, and several more in other countries. The habits of our two rats are quite different, and the first thing to find out if you want to rid a building of rats is which species is infesting it.

As for the word race, it has so many different meanings as to be useless in scientific discussion, though very useful for getting members of the same nation to hate one another. If it means a group of people with very similar inborn physical characters, especially of skin and hair, then we ought to talk of red-haired people as constituting a special race. If it means people who talk similar languages, as when the phrases Aryan race or Slavonic race are used, then American negroes and whites belong to the same race, and Basques to another.

In fact our discussions of race are still at the pre-scentific level, as would be a discussion of whether the mustard at breakfast was hotter than the tea. The same is true of most discussions of intelligence. No doubt our descendants will be able to treat these matters scientifically. But we cannot do so yet, and we should be extremely suspicious of people who say that they can. They are very often trying to do in Britain what the theoreticians of the Nazi movement did in Germany.

What "Hard" Means

IN the last article I wrote about the way in which ordinary words change their meaning as they are used in science and technology, taking as an example the word "hot". All adjectives start as descriptions of qualities. They end up as descriptions of quantities, if they are taken over by science. A word like "big" or "long" is entirely relative. A mile is a long swim but a short walk, because an ordinary man often walks a mile, but seldom swims a mile. A man is large compared to a cat, and small compared to an elephant, and so on. This sort of contradiction does not trouble anyone but philosophers, because we are accustomed to measure lengths, and we all know what a foot or a mile means.

But we are in much greater difficulties with some other common adjectives such as "hard". Of course we use the word metaphorically, as when we talk of a hard question, meaning one which is difficult to answer, or hard X-rays, meaning rays which penetrate easily through matter. But I want to deal with the word in its ordinary sense, as when we say that iron is harder than butter. Everyone will agree that this is true. But it is not so easy to decide which of two pieces of iron is harder, and as a matter of fact there may be no definite answer to the question. When we come to accurate measurement, we find that the word "hard" has dozens of slightly different meanings.

The most usual test of hardness in steels is that of Brinell. A very hard steel ball of 10 millimetres diameter is pressed onto a steel plate for 30 seconds with a load of 3 tons. The hardness number decreases with the depth of the indentation.

Another test of hardness which generally agrees pretty well with the Brinell test is the weight which must be put on a diamond point in order that it should just produce a visible scratch when pulled sideways. But as soon as we use moving bodies to measure hardness things become very complicated. For example at a relative speed of 30 feet per second a disc of "soft" iron was cut by a steel tool; at 100 feet per second the disc cut the tool itself, and at 300 feet per second the disc cut quartz. In the same way hardness varies with temperature.

If we compare an ordinary hardened carbon tool steel and a high-speed tool steel at ordinary temperatures, the former is probably a little harder by the Brinell test. But at a dull red heat the high-speed steel is still hard, while the ordinary tool steel is about as soft as is copper at room temperature. As machine tools heat up during high-speed work, their hardness at high temperatures may be all-important. Now these high-speed tool steels all contain tungsten, and plenty of it. Probably the same properties are required both in the armour plate of tanks, and in the noses of projectiles to pierce them.

High-speed steels of ten years ago (for later developments are secret) contained anything from 15 to 25 per cent of tungsten, along with 2 to 7 per cent of chromium, and in some cases molybdenum and vanadium. In fact in a typical high-speed steel less than 60 per cent of the total is made up of iron. The other elements mentioned all have higher melting points than iron, that of tungsten having the enormously high value of 3370° C, as compared with 1500° for iron.

At the present time the Germans rely on Spain and Portugal for their tungsten. For some reason this metal is invariably referred to in the press by its German name of wolfram. The rulers of these countries have promised to cut down the supply of this metal to Hitler to some extent. As they have habitually broken their promises in the past, there is no particular reason to suppose that they will keep this one. British soldiers will continue to die in large numbers on account of the Hoare-Halifax-Laval policy of appeasement to Fascism, which still governs British policy to Spain and Portugal.[1]

Hardness is also used as a measure of the amount of wear which a material will stand. But here again the details are very important. We may want to test how a metal stands up to rolling friction without lubricant. This is essential in tests of rails, and wheels of railway vehicles. Or we may want to know how a metal stands up to sliding abrasion, either with or without a film of oil. One steel may stand up better to rolling friction, and another to sliding friction. Here their differences in hardness probably depend on the fact that metals sliding over one another actually melt at the point of contact, so their properties at high temperatures become important.

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[1] This export was finally stopped by the Maquis, not the Foreign Office.

Within a century or less we shall probably be able to calculate the various kinds of hardness with great exactitude from a knowledge of the forces between atoms. At present we can only do so very roughly. Probably [illegible]ysicists of the future will be able to specify the different kinds of hardness very completely in terms of a few numbers.

It would be possible to deal in the same way with the meanings of various words such as toughness, elasticity, and brittleness, which are applied to solids. None of these can be expressed by a single number.

The properties of liquids are a good deal simpler than those of solids, and the properties of gases are simpler still, though anyone concerned with the design of aeroplanes finds even gases quite complicated enough. And when we come to such a property of material systems as life, the complications are of course vastly greater. Scientists are reproached because they cannot say in simple terms what life is. It is easy enough to point out differences between a dog or a cabbage and a stone or a machine. It is much harder to draw the line when we get down to the agents of smallpox and other diseases, which behave in some ways as if alive and in others as if dead. But if anyone reproaches science because it cannot yet give a complete account of life, it is a fair reply to ask him what he means by hardness, and how he would tell if one thing is harder than another.

Control Experiments

ONE of the features of scientific research which the ordinary man finds hardest to understand is the necessity for what are called control experiments. We alter a system in some way, and something happens. We are apt to assume that we know why it has happened.

For example a sleepless man is given an injection of a drug, and falls asleep in ten minutes. We assume that the drug is responsible. We pass an electric current through a coil, and a piece of metal moves. We assume that the current has produced a magnetic field. But in both cases we have done something quite complicated. The man knows that he is getting an injection, and the nurse tells him that he will be able to sleep now. In passing the current through the coil, we have not only made it magnetic, but have warmed it, and caused other changes in it. Perhaps the injection only put the man to sleep because he believed it would do so, or the current only acted by heating the coil. Hence, if we are to be scientific, we must try whether the man will sleep if the nurse injects salt and water, and whether the metal moves if the coil is warmed with hot water or a flame. These are elementary control experiments. They are certainly not enough. If the man goes to sleep a faith healer might say that this proves that drugs are unnecessary. But the dummy injection may not work at first, though it is quite efficient after the drug has acted half a dozen times, and the man has got the habit of going to sleep when an injection is given.

A very important type of control experiment is this. We have treated a living creature or some other complicated system with a chemical substance, and got a clear-cut result. But are we sure that this is not due to a trace of impurity in the chemical concerned?

It may be so. The sheep in one area of New Zealand used to die of a disease, one of whose symptoms was anaemia, that is to say, their blood contained too little of the red pigment, haemoglobin. Many cases of human anaemia, though not all, are improved when fed with iron salts. Iron salts had a dramatic effect in curing the sheep. It looked a clear case of cause and effect, but since green plants always contain iron, and will not grow without it, it was hard to see why the sheep were short of it. And occasionally iron salts did not work. Finally it was found that the cure was not due to iron at all, but to cobalt. This is a metal with properties fairly close to those of iron, and generally found as an impurity in it. The soil in the areas of New Zealand where the disease occurred contained enough iron for the sheep, but not enough cobalt, and the cobalt present as an impurity in commercial iron salts had cured the sheep. Since then cobalt-deficient pastures have been found in England and other countries, and quite small amounts of cobalt salts scattered on them are enough for the sheep. It is still uncertain just why cobalt is needed for the making of blood; and it is iron, not cobalt, which is most often needed in human anaemia.

One of the big, and perhaps inevitable, defects of science as taught in schools and universities, is that experiments are designed to "come off" and the difficulties found in research work are avoided. I wonder how many students could give a satisfactory proof that the tests which they have learned for various elements, or the effects on plant growth which they have seen, were not due to small quantities of impurities in the substances they used.

Controls are especially important in medicine and agriculture, where a great many conditions are varying at once. If the death-rate from a disease falls after some new remedy has been tried, this is far from a proof that it is of any use. The medical officer in the district may have got more interested in the disease, so that even the mildest cases are reported, and if so the percentage of deaths naturally falls. Or the disease may have become less deadly for some unknown reason. The farmer or smallholder who starts using a new compost is quite likely to look after his plants better in other ways also, and to put the increased crop down to the improvement in the soil. So the workers at agricultural experimental stations have to take care to vary only one condition at a time, and to lean over backwards, so to say, in order to be sure that they are not unconsciously helping to prove what they want to prove—or what Imperial Chemical Industries want them to prove.

Critics of Marxism say that politics cannot be scientific because you cannot do controlled experiments, for example running 20 factories under ordinary capitalism, 20 similar ones under state capitalism, and another 20 under democratic socialism, and comparing their efficiency. So it is worth pointing out that in many sciences experiment is impossible. You can't discover experimentally how the tides would behave if the moon went round the earth once a week instead of once a month, or what sort of rock would have been laid down if England had been deep under the sea at the time when our coal seams were formed. Nevertheless astronomy and geology are sciences. Marxism became more scientific as it developed into Leninism and Stalinism. The Bolsheviks had a correct political and economic theory. But that was not enough. They experimented on a great scale. For example they tried state farms and collective farms. The latter worked better in most cases, though, for all we know, state farms might work better in a Socialist Britain. They were able to compare the results of different experiments, for many types of productive relation are possible under Socialism. Above all, as any reader of the History of the C.P.S.U. finds out, they learned from their mistakes in a truly scientific manner. Leninism is not only a historical science like geology. It is an experimental science because Leninists make history as well as studying it.

Adventures of Words

ONE of the first things a Marxist learns is that everything has a history. Nothing has existed for ever in its present form. Some things have a long and important future, others are going to perish very soon. Thus the biologist can trace the ancestry of men and bisons, and say, that, as there are two thousand million men, of whom about one-tenth are already seriously planning their future, and only about two thousand bisons, preserved as curiosities, men have more of a future than bisons.

The sociologist can compare the young and vigorous Socialist state and its institutions, such as soviets, collective farms, and state planning commission, with capitalist states and their institutions such as stock exchanges and hereditary titles, and also with more primitive societies such as African tribes and their polygamous chiefs and rain-making wizards. And he can forecast where the future hope of mankind lies.

Today I am concerned with the history of words. Some merely change their form, but not their meaning. The stablest of all are numbers. "Four" and "seven" have changed a little from their Anglo-Saxon forms "feower" and "seofon", but their meaning has not changed.

One might think that words for common and easily recognized things, such as animals, could not change their meaning. But some are doing so today. A hundred years ago a kid generally meant a young goat. Now it generally means a human child. Quite likely the old meaning will be forgotten in a hundred years. The Anglo-Saxon word for cattle was "feoh". As payments were commonly made in cattle, it also came to mean a payment, and has survived in the modern "fee". It is also the root of such words as fief, feudal, and feu, which is the Scottish word for a lease. They all refer to payments in kind by peasants who very likely never saw a coin in their lives. On the other hand our word "cattle" is derived from the Latin "capitale", meaning stock, from which the word "capital" also comes. If our language had developed a little differently, Marx's greatest work would be called "Cattle".

Naturally names describing social position change as society changes. In an Anglo-Saxon house the husband was called "hlafweard", or loaf-warden, his wife the "hlaefdige", or loaf-kneader, and the servant "hlafaeta", or loaf-eater. "Hlaf" is derived from the same root as the Russian "khleb", for bread, and "dige" from the same as "dough". The first of these words have gone up in the world, and become "lord" and "lady". Perhaps Lord Woolton might be called a loaf-warden, but very few peeresses would be much use at baking today. The social changes in the next hundred years may be as great as those in the last thousand, and it would be interesting to guess which of our words of today will be regarded as specially honourable in 2042. I think "comrade" is one of them.

If substantives change their meaning, adjectives turn somersaults. I will only instance "jolly" and "nice". The Greek word "diabolos" means originally one who throws through, as a good bowler throws through the batsman's defence. Then it meant a prosecutor, including the angel who was supposed to accuse men to God. This accuser was also supposed to be a tempter, like the officials who today try to get clothes without coupons, and "diabolos" is the root of "devil". A mediaeval Latin word for devilish was "diabolivus". As long as Christianity was a people's religion, the devil was regarded as an enemy. But in the Middle Ages the Church as a whole was lined up with the nobles against the people, though it produced a number of priests like John Ball who died for freedom. Hence many people regarded the devil as a friend, and "diabolivus" has become "joli", or pretty, in French, and "jolly" in English.[1]

"Nice" is derived from the Latin "nescius", ignorant, and meant foolish, weak, or simple, in mediaeval French. In

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[1] This derivation is due to Wheatley. Not all etymologists agree with him.

Elizabethan English it meant trivial, as in Shakespeare's "every nice offence". Then it came to mean accurate, as in the modern word "nicety", and still later to mean pleasant, perhaps because craftsmen enjoy accuracy.

When the history of our country is taught as the history of social change, the history of our words will be used to illustrate it, and such facts as these will be part of our general education.

What Use is Philosophy?

G. ALEXANDROV and four colleagues have just been awarded a Stalin prize of 200,000 roubles for a three-volume book on the history of philosophy. Most of the other prizes went to scientists. Many people will be inclined to say, "Why rank with scientists men who have merely described the opinions, mostly false, held by a number of people in the past? No doubt this has some interest, like a history of fairy tales or astrology, but it isn't much use, particularly at the present grim moment."

There are a great many reasons for studying what philosophers have said in the past. One is that we cannot separate the history of philosophy from that of science. Philosophy is largely discussion about matters on which few people are quite certain, and those few hold opposite opinions. As knowledge increases, philosophy buds off the sciences.

For example, in the ancient world and the Middle Ages philosophers discussed motion. Aristotle and St. Thomas Aquinas taught that a moving body would slow down unless a force were constantly applied to it. They were wrong. It goes on moving unless something slows it down. But they had good arguments on their side, and if we study these, and the experiments which proved them wrong, this will help us to distinguish truth from falsehood in the scientific controversies of today.

We also see how every philosopher reflects the social life of his day. Plato and Aristotle, in the slave-owning society of ancient Greece, thought man's highest state was contemplation rather than activity. In the Middle Ages St. Thomas believed in a regular feudal system of nine ranks of angels. Herbert Spencer, in the time of free competition between capitalists, found the key to progress in the survival of the fittest. Thus Marxism is seen to fit into its place as the philosophy for the workers, the only class with a future. But we can hardly guess what the world will look like to men and women with several generations of communism behind them, who take the brotherhood of man for granted, not as an ideal to be aimed at, but a fact of life, and yet know that this brotherhood was only achieved by ghastly struggles.

The study of philosophies should make our own ideas flexible. We are all of us apt to take certain general ideas for granted, and call them common sense. We should learn that other people have held quite different ideas, and that our own have started as very original guesses of philosophers.

If a dog could speak, it would probably not distinguish between motion and life. Some primitive men do not do so, and travellers interpret them as saying there are spirits everywhere. In our age of machines we are apt to look for mechanical explanations of everything, yet it is only three hundred years since machines had been developed so far that Descartes first suggested that animal and human bodies were machines.

A scientist is apt to think that all the problems of philosophy will ultimately be solved by science. I think this is true for a great many of the questions on which philosophers still argue. For example Plato thought that when we saw something, one ray of light came to it from the sun, and another from our eyes, and that seeing was something like feeling with a stick. We now know that the light comes from the sun, and is reflected into our eyes. We don't know in much detail how the changes in our eyes give rise to sensation. But there is every reason to think that as we learn more about the physiology of the brain, we shall do so, and that the great philosophical problems about knowledge and will are going to be pretty fully cleared up.

But if our descendants know the answers to these questions and others which perplex us today, there will still be one field of which they do not know, namely the future. However exact our science, we cannot know it as we know the past. Philosophy may be described as argument about things of which we are ignorant. And where science gives us a hope of knowledge it is often reasonable to suspend judgment. That is one reason why Marx and Engels quite rightly wrote so little on many philosophical problems which interested their contemporaries.

But we have got to prepare for the future, and we cannot do so rationally without some philosophy. Some people say we have only got to do the duties revealed in the past, and laid down by religion, and God will look after the future. Others say that the world is a machine, and the course of future events is certain, whatever efforts we may make. Marxists say that the future depends on ourselves, even though we are part of the historical process. This philosophical view certainly does inspire people to very great achievements. Whether it is true or not (and I think it is true) it is a powerful guide to action.

We need a philosophy, then, to help us to tackle the future. Agnosticism easily becomes an excuse for laziness and conservatism. Whether we adopt Marxism or any other philosophy, we cannot understand it without knowing something of how it developed. That is why a knowledge of the history of philosophy is important to Marxists, even during the present critical days.

Is Psychology a Science?

READERS frequently write to me on psychological questions. Some are questions of individual psychology. "How should I get over my fear of so-and-so, or my irrational objection to something else?" Obviously I cannot answer them. Even a psycho-analyst cannot do his work by correspondence, but must talk with his patient for many hours before he gets any result. The only general advice for such people is that one often overcomes internal difficulties if one has a big enough interest outside oneself. Readers of the *Daily Worker* should certainly be able to find one. But I am not at all sure that psychology is part of my job. I do not think it is a science yet, though I think it is on the way to becoming one. History shows that science has gradually extended its field, and that what was a mystery to our ancestors is understood, and often controlled, by ourselves.

A fully developed science has two characteristics. In the first place it consists of statements which can be checked. When a zoologist or botanist names a new species it is not enough to describe it. He must deposit a type specimen in a museum so that his colleagues can verify his description. I know a man who believes that he has found the cure for a serious disease, and that there is a conspiracy of doctors and scientists to prevent him from publishing full accounts of his work. I have seen a paper which he wished to publish, and do not believe in the conspiracy. For the account of how he made his remedy was so vague that no-one could repeat his preparation and see if they got the same results.

A lot of the statements made by psychologists cannot be checked, because we cannot inspect another person's mind. The behaviourist school think that psychology should only be concerned with peoples' actions, and not with their consciousness. I do not agree. It seems to me a scientific fact that very hot water produces a kind of consciousness which is like that produced by a broken bone or a blow with a whip, and which we call pain. But a great many statements about consciousness cannot be checked, and a fair number are clearly false.

Secondly the fully developed sciences form a unity. They all link up with physics, and can be stated in the language of physics, though they have their own language. Thus the statement that white mice with pink eyes always breed true can be put in terms involving wave-lengths of light, and other physical notions, though it would be tedious to do so. In other words science becomes more materialistic as it grows. This does not mean that biologists think that a mouse is a machine. Only a few of them do so, and there are no Marxists among them. But very few think that a mouse is only a set of sensations, or that it is matter plus an immaterial soul.

At least three branches of psychology are already scientific. One is the exact study of sensations. Probably every British psychologist working in this field is now engaged on war work. To take one example, it is essential that a night pilot should be able to see every indicator on his machine clearly, so as to know his height, how much petrol he has left, in what direction he is flying, and so on. But he must be able to look from any of them into the air without being dazzled, and detect an enemy bomber. And he must be able to do this at a great height, and when fatigued. So psychologists must study the best possible system of lighting, and the effect of oxygen want, fatigue, and other conditions, on night vision. They must also devise tests to pick out men who are particularly suited for this work.

The psychology of skilled work is equally important. Industrial psychology has made considerable progress in capitalist countries, but it has been mainly studied from the employer's point of view. And the workers have been justly suspicious that it is only used to increase profits by speeding up work. In the Soviet Union a great deal of similar work has been done, particularly in a great institute at Kharkov. It has helped to provide a scientific basis for the Stakhanovite movement. Unfortunately very little is known of this work in Britain.

Finally we come to the statistical study of individual abilities.

The problem is essentially a practical one. How can we devise a simple series of tests to determine whether a boy or girl is likely to be a success in a particular job, say a bus driver, a dentist, or a salesman? The only way to discover this is by trying a great number of tests and seeing how far the results agree with one another, and which is the best practical guide. Unfortunately a lot of nonsense has been written about their results. An "intelligence" test is apt to mean a test for a mind which works like that of a professor. But the professorial brand of intelligence is not the only kind.

In the United States, European and Chinese children do about equally well on intelligence tests, but negroes and red Indians are not so good. This does not prove that they are stupid. The Indians were superior to Europeans at hunting, tracking, and finding their way in forests. I should like to see the results of tests devised by a negro or a red Indian. Very possibly Europeans would not do so well on these. Again it has been supposed that these tests are measures of inborn ability. But it has been conclusively shown, by studies on adopted children, that environment counts for a great deal, though it is not yet certain for how much.

The psychology of the intellect, emotions, and will, can only become fully scientific when we know as much about the brain as we know about the eye and other sense organs. As the brain is much more complicated and less accessible than the eye, this will take a long time.

Some critics of Marxism say that we cannot apply scientific method to politics until we understand the psychology of the individual. This is incorrect. We knew a great deal about the behaviour of solids, liquids, and gases, consisting of large numbers of atoms, before we knew anything about the atoms. In the same way we can predict human behaviour in the mass, without knowing whan an individual will do. We know that if the price of cigarettes rises, fewer will be bought. We do not know if Mr. Smith will economize on fags or movies. Though Marxism will certainly benefit from advances in individual psychology, it is already a genuine and scientific analysis of human behaviour in the mass.

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SCIENCE AND WAR

Air Raid Noises

BY now,[1] unfortunately, most of the people of Britain know the rising and falling hum of a two-engined bomber. This is an example of the phenomenon called interference, which happens whenever two trains of waves start out from nearly the same place with nearly or quite the same periods. In the case of a bomber it occurs when the two engines are not quite synchronized. Suppose that one is sending out sound waves 200 times a second, and the other 201 times, then once a second the two engines will be firing in time with one another. The two sets of sound waves will reinforce one another, and the sound will be loud. And once a second they will interfere with one another, and the sound will fade out.

This is interference in time, but we can also get interference in space. If the two engines are synchronized, and some distance apart, there are places where the sound waves arrive together, and the noise is loud, and others where they cancel one another out, and there is comparative silence. If the aeroplane were stationary, these would form a pattern on the ground. Owing to the speed of bombers, this effect cannot be noticed.

But effects of this kind are easily noticed with light. Everyone knows the rainbow-like effect of a film of oil on water, or a film of air between two glass sheets. This is due to a simple kind of interference. Some of the light is reflected from the near surface of the film. Some goes through to the far side and is reflected there. If the extra length of path is just one, two, three, or some whole number of wave-lengths the light is increased. If it is just a half, one and a half, or some such number, the light is extinguished. So with a one-coloured light, such as that from a sodium lamp, we get a pretty simple pattern of light and dark bands.

White light, which is a mixture of many colours, naturally gives a more complicated pattern. Interference of this kind has been used both for measuring the wave-lengths of light and the thicknesses of various kinds of films. One of its most striking applications was the measurement of the size of a "fixed" star. Just as interference can be used to measure very small distances such as the thickness of an oil film, it can be used to measure very small angles, such as that between the rays of light coming to a telescope from different parts of a distant star. The stars measured in this way were all very large ones, far larger than our own sun. But the results obtained agreed very well with calculations based on the luminosity of the star, its distance, and its temperature, which can be roughly measured from its spectrum.

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[1] 1940.

Other painfully familiar sounds are those of falling bodies, either German bombs, or parts of British anti-aircraft shells. All bombs fall considerably more slowly than the speed of sound. So they give some warning of their approach, unlike bullets, or shells from many types of gun, which travel quicker than sound, and therefore give no warning. If a bomb were falling through empty space containing no air, and if we neglect the speed of the bomber, it would have to fall for 19,000 feet to get up to the speed of sound, which is 1100 feet per second. This fall would take over half a minute. Allowing for the bomber's speed, a fall of 15,000 feet would be needed. But the air resists its fall, and a good deal of the energy which would otherwise be converted into motion is made into sound. Some energy is also used in stirring up the air, and in heating the bomb and the air.

In consequence, even if dropped from a greater height than 19,000 feet, and even though they start with a considerable horizontal speed from the motion of the bomber, bombs do not move as quickly as sound, though they may get up a speed of 900 feet per second. Any falling body finally attains a nearly constant speed at which the resistance of the air is equal to its weight. For small shell splinters falling from a great height this speed is not very large, though they can break glass. Larger splinters or shell caps can smash a roof or kill a man. And a quarter-ton bomb with a delayed-action fuze can pierce half a dozen 6-inch cement floors before bursting. For not only does it weigh more than a smaller one, but it can get up a greater speed.

So far I have written of sounds, which are periodic changes in air pressure, moving at 1100 feet per second. The blast wave, however, is of a different kind. It travels faster than sound, though not very much so outside the flush area. And it is not periodic. On the contrary the pressure rises with extreme speed to a very high value, and then falls back below normal. In fact there is a period of suction which lasts much longer than that of pressure, though it is not so violent. The whole thing is over in a small fraction of a second, save for very slight changes.

These facts explain many of the effects of blast. If a bomb bursts in the street, window glass is generally driven into houses close to it, but further away the suction wave may pull it out. This is particularly so round corners. The suction wave can turn a corner more easily than the pressure wave. The effect of blast on windows is apparently erratic, but follows definite laws. If you try to rock anything, for example a car, a lot depends on the speed at which you work. If too quick or too slow, nothing much will happen. If you manage to push in harmony with a natural period of the car, you will get it moving.

So with a window. Glass panes have a natural period of vibration, generally round a hundredth of a second. If the blast wave sets a pane vibrating in this way it may break, when a larger pane with a longer period or a smaller one with a shorter period will escape. Again as the blast wave goes down a street, it is reflected from one side to the other, and if the original and reflected waves arrive at the right interval, the two together may smash a pane whilst one alone does not.

Unlike the blast wave in the air, the shock wave in the ground is fairly quickly converted into a series of periodic waves. Even 20 yards from a bomb explosion the ground moves to and fro several times. If you can count the number of these waves and time their frequency, that is a proof that you have a more scientific temperament than I have.

Such a frame of mind is very well worth acquiring. Any Marxist who can do so will at least be able to see our present suffering as part of the historical process, something which unfortunately seems to be inevitable before people will wake up to the truth and shake off capitalism. The more people can acquire that frame of mind, the sooner we shall be out of the wood.

Seeing in the Black-out

COUNTRY dwellers often have to find their way about in the dark. But some townspeople have had this experience for the first time in their lives during the black-outs. And a number have been killed, either because drivers could not see pedestrians, or because pedestrians thought a dimly lighted car or lorry was a hundred yards away when it was on top of them. The black-out regulations are being made more sensible, but something can be done from the human end as well as the mechanical one.

Some animals can only see in the daylight. Hens are quite blind in ordinary twilight. Others, such as owls, can see better in moderate darkness than in daylight. Men can see both in strong and dim light, but not without preparation. The process of adaptation takes some time. If we come out of darkness into strong light we are dazzled, and the light may even be painful, but we can see all right in a very few minutes.

But adaptation to darkness takes half an hour to complete, and is often very poor even after ten minutes. The first thing that happens when we go from light into darkness is that the pupil of our eye gets bigger, so that more light enters. But this only increases the sensitivity about five times. The same principle is employed in a camera, where different stops are used. The main change is a chemical change in the retina, as the sensitive film at the back of the eye is called. This consists of the building up of a purple substance called rhodopsin which plays a part in the eye like that of silver bromide in a photographic plate. If this is allowed to go on for half an hour the sensitivity of the eye is increased about ten thousand times. That is to say the dimmest light that can just be seen is one ten-thousandth of the brightness of one which could just be seen before adaptation. Or the same light can be seen one hundred times as far away.

Dark vision has some peculiarities, which ought to be generally known. As a coloured light gets dimmer its colour disappears. First of all blue light appears white; then green, yellow, and last of all red, lose their colours. This is why red lights are used for warning. In daylight we can see a thing best by looking at it, but in nearly complete darkness we see it best if we look at something else. Finally, in the dark even the sanest people see vague moving shapes when there is nothing to see. Sentries soon learn to allow for this fact.

The practical lesson to be learned is this. No-one should start to drive a vehicle in a black-out until he or she has been in the dark for at least five minutes; and ten or fifteen are better. If you light a match to smoke, remember that this will cut down the power of your eyes for several minutes. Pedestrians should take the same precautions. Never attempt to cross a road immediately after coming out of a lighted building. Walk along the pavement for a few minutes first. When you cross remember that it is very hard to judge the distance of a dim light. That car may be much nearer than you think!

So far I have written as if everyone were equally good at dark adaptation. This is not so. I am better than most, as I found when patrolling no-man's-land at night during the last war. A few people are night-blind like hens, and cannot even see the stars, let alone find their way by starlight. Many are intermediate. Before you start driving in black-outs you should compare your vision with that of a real expert. There is no disgrace in being night-blind, but it is disgraceful to drive, and thus risk your fellows' lives, if you are so. Some night-blindness is inborn. But a great deal is due to undernourishment. Dr. Harris of Cambridge found that 90 per cent of "public" schoolboys, but only 45 per cent of elementary schoolboys and 50 per cent of their mothers had good night vision. The defect can generally be cured by giving plenty of vitamin A, which is one of the components of rhodopsin. The cure takes several weeks. The best sources of vitamin A in ordinary diets are butter and margarine. But very concentrated preparations from fish-liver oil are available. If employers issued these to bus and lorry drivers, a number of accidents would be avoided. This will be still more vital when butter is rationed.[1] Already the butter shortage is causing night-blindness in Germany, so their black-outs must be even more dangerous than ours.

If these simple rules were followed we could, I believe, save dozens of lives a week, and avoid some hundreds of minor accidents. At the present time, when the nation needs all our effort, and every bed in every hospital, this is supremely worth doing.

[1] This was written in 1939.

Death Rays

DURING the last war the press was full of stories of death rays, and there were even more during the period of preparation for this one. Some inventors made quite tidy sums out of credulous admirals and generals. I wish these stories were true. A death ray is just the thing to bring down bombers. If every town in Britain had one, we could turn up our lights again, and the children could come back.

Here is the reason. A searchlight operator may catch an aeroplane in his beam, but it does not follow that an anti-aircraft gunner will hit it. If the bomber is two miles up, the light from the searchlight takes one hundred-thousandth of a second to reach him,—during which time the bomber, if it is going at 300 miles per hour, has moved a twentieth of an inch. So the bomber can no more hope to escape the searchlight by mere speed than a snail can escape from a greyhound.

Now suppose a gunner fires a shell at the bomber, and suppose the average speed of the shell is half a mile a second, which means a muzzle velocity well above this, the shell takes four seconds to reach the plane. During these four seconds the plane has moved 600 yards. To score a hit the gunner must estimate the plane's speed correctly, and if the pilot is dodging, he must be a thought-reader too. Even if the shell passes within a foot of the plane, it won't hurt it unless it bursts at the right height, which means very careful work with the time fuze. So anti-aircraft artillery is not very dangerous unless there is a great deal of it. An attack on a fleet protected by hundreds of anti-aircraft guns is no joke. But in an attack on a town defended by two or three,[1] it is bad luck for the bombers if one of them is hit.

Now suppose that, instead of the searchlight beam, the defenders had some kind of ray which, the moment it touched the plane, would set it alight, stop its engines, or kill the pilot, things would be very different. We should, in effect, be giving the gunners a gun with a muzzle velocity increased nearly half a million times, and no need for fuze-setting. No wonder both inventors and journalists who do a little wishful thinking are keen on death rays.

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[1] This was written in 1939.

The idea of using rays in warfare goes back to very ancient days. More than two thousand years ago the Romans besieged the Greek city of Syracuse. Among the besieged was the greatest scientist of the age, Archimedes. He probably designed catapults and other machines to sink the Roman ships. And there is a story that he concentrated the sun's rays with lenses, and set them alight. We know that this is untrue. To set a ship alight even fifty feet away would probably need a lens 20 feet across, and the Greeks could not make them. They cannot be made today. Perhaps, however, he tried to make such a lens. Or perhaps the Syracusan Ministry of Information dropped leaflets over the walls saying that he was going to. Anyway this first death ray was no good, and the Romans took Syracuse and killed Archimedes.

As far as I know, the first modern death ray was invented by Mr. H. G. Wells. It was used by invaders from Mars to destroy several English towns, and rout the British army. This ray was a searchlight sending an invisible beam of heat. If it touched an inflammable object, this caught alight at once, while iron and steel melted in a few seconds. In the same book the Martian invaders used shells with poisonous gas. As the book was written in the 19th century, this shows that Wells was thinking well ahead of his own time. Nevertheless the heat ray won't work. A simple calculation shows that any substance hot enough to send out such a ray would not merely melt, but explode into fiery gas in a tiny fraction of a second. So although gas shells are quite practicable, anyone who tried to produce a Wellsian heat ray would merely blow himself up.

At the time when Wells wrote *The War of the Worlds* physicists were discovering all sorts of invisible rays. Besides visible rays, infra-red rays with heating power, ultra-violet rays with chemical activity, X-rays, and beams of radio waves, which can be regarded as rays, were being discovered.

Among all these it was quite natural to think that some were likely to be very deadly, just as of the thousands of new chemicals which were made each year, a few turned out to be very poisonous, though most of them were harmless.

And in fact some of these new rays were rather deadly. Ultra-violet rays blister the skin, and X-rays kill as well as cure. A lot of the first group of surgeons who worked with them were killed. And it wasn't a pleasant death either. Their skins were injured, and the "burns" not only would not heal, but often developed into cancer, which killed them after years of suffering. This sort of thing would be little use as a military weapon. A battalion would not be stopped from attacking because they were liable to die painfully five or ten years later. They would probably be told by the Staff that the threat was merely enemy propaganda. And we know that this sort of threat does not frighten people. Almost every man who worked a rock drill in Cornwall or Johannesburg thirty years ago died of phthisis within fifteen years. But wages were good, and there was no difficulty in getting drillers.

We know now that all kinds of rays are periodic electromagnetic disturbances moving with the speed of light. They differ according to their wave-length, or what comes to the same thing, the number of cycles per second. Long waves measured in miles or hundreds of yards are the ordinary radio waves. Those measured in inches are the short radio waves. All of these are harmless, though a powerful beam of very short waves warms you up if it passes through you. Then come still shorter waves, measured in thousandths of an inch. These form infra-red rays, which have a decided heating effect, but are not dangerous. Nor, of course, are visible rays. Still shorter waves form ultra-violet and X-rays, which are dangerous.

But they cannot be used in war for a very interesting reason. The air is not quite transparent to them. Most of the ultra-violet rays which start from the sun are stopped by the air. Even at the top of a mountain the sunlight has more sunburning power in relation to its heating effect than at sea level. And the sunburn is due to the ultra-violet components of sunlight. Men could quite well walk about on the moon breathing oxygen in pressure suits such as are used by high fliers. But if these had quartz face-pieces which let through the ultra-violet components of sunlight, they would be frightfully blistered. Natural selection has seen to it that we are not much injured by any rays which will go through even a few hundred feet of air, though animals which live permanently underground are often killed by ordinary sunlight. This is why even if we had a source of ultra-violet radiation so powerful that we could use it for close-range fighting, it would be absolutely useless at a range of even half a mile.

There is one kind of death ray which is sometimes thought to be effective on the basis of model experiments. This is a beam of ultra-violet rays so strong that it makes the air conduct electricity. The idea is to shine such a beam on an aeroplane, and then pass a powerful electric current along it. This is however useless, for the reason that such beams are quickly stopped by air, and indeed if air did not stop them they would not make it conduct.

For such reasons as these scientists will not believe in death rays. One inventor demonstrated one about 1915 which, he said, killed a sheep. Certainly the sheep died, but the Government department which was offered the ray insisted on doing a post-mortem examination on the sheep, and found a quite ordinary poison. Still I suppose the present Inventions Board have to examine several specifications for death rays every week, and may even have to test a few.

Finally there are rays which are alleged to stop engines. How they are to get through even a thin layer of metal we are not told. But about ten years ago the Germans were reported in the press to have brought down some French aeroplanes by this means. If it were anything but a romance they would be using it now. An inventor demonstrated a ray of this kind to the Admiralty, and a number of cars suddenly stopped in the street when he turned it on. But as an official car was unaffected, it was thought that these cars must have been driven by his friends.

I wish there was a death ray. But it is going to take a great deal to make me believe in it.

The Commonest Poison Gas

ONE of the Regional Commissioners has recently[1] warned people of the danger of warming air raid shelters by means of stoves or braziers. Several people are already said to have been killed in this way. The warning is fully justified. But it ought to have been given before the people were killed, and given to the whole country.

An ordinary flame, such as that of a candle or an oil lamp, uses up oxygen, and burns oil or grease to form carbon dioxide and water vapour. In fact it changes the air in the same way as a human being breathing, except for a small amount of fumes which smell but are harmless. But things are different when the burning is incomplete. This may occur for several reasons. If a flame plays on a cool surface, for example the underside of a kettle, the process of combustion is suddenly stopped, and some of the gases in the flame do not combine fully with oxygen.

The most important gas produced in this way is carbon monoxide, CO, as opposed to carbon dioxide, CO_2. This is also formed in a coke brazier, because the air flow through the red-hot coke is not enough to burn it completely. Some of the carbon monoxide burns above the coke with a dull blue flame, taking up another atom of oxygen to become carbon dioxide; but some of it gets away.

Now carbon monoxide is a fairly poisonous gas, though nothing like as poisonous as chlorine, phosgene, and others used in war. But it is dangerous because it is one of the fortunately rare gases which poison you without preliminary warning.[2] If you are poisoned by phosgene in a gas attack or by nitrous fumes in an explosive factory you will cough and gasp a good deal. You may then feel much better, and suddenly fall unconscious when you think you have recovered. But you certainly know something is wrong before you lose consciousness.

[1] September 1940.

[2] See Note on p. 161.

But carbon monoxide, hydrogen cyanide, and arsine have very little smell and cause no irritation. The chemical textbooks state that carbon monoxide has no smell. This is untrue. It has a faint smell like garlic. But you can't smell it in a dilution of one part in a thousand, which is quite enough to kill you.

Fortunately the commonest source of carbon monoxide in ordinary life is in coal gas, where it is accompanied by smelly substances which give some warning. But if a gas main is broken, for example by a bomb explosion, the gas may leak out through soil which filters off the odorous vapours in the coal gas and leaves the carbon monoxide behind. Thus it may penetrate into neighbouring houses, particularly the basement, and kill people before they smell it. I do not know if anyone has yet been killed in this way during recent months, but such cases have occurred in peace, and are likely in war.

Carbon monoxide kills in a very simple way. In fact it is the only poison whose action is pretty completely understood. Our blood contains a substance called haemoglobin which is purple, but easily combines with oxygen and then becomes red. As the heart pumps the blood round it picks up oxygen in the lungs, and carries it to the various organs in the body. Here it gives up some of its oxygen, and comes back more or less purple. This change is responsible for the bluish colour of veins, and the bluish colour of the lips if the heart or lungs break down. After death the blood does not circulate, but the tissue cells do not die at once and go on using oxygen, so the blood becomes purple, and the face of a dead person looks greenish until the blood has drained out of it.

Now carbon monoxide also unites with haemoglobin to give a red compound slightly more yellowish than the oxygen compound. When the haemoglobin is combined with carbon monoxide it can no longer carry oxygen. When half your haemoglobin has combined with carbon monoxide you can hardly stand, and may faint. When three-quarters have combined you die from want of oxygen. But the blood remains red, so the faces of people who have put their heads in the gas oven preserve their natural colour for some time.

This property of the blood renders carbon monoxide one of the easiest of all poisons to detect.

The lowest fatal concentration of carbon monoxide is about one part in two thousand of air. But at this concentration it takes about half an hour even to make you unconscious, whereas one part in a hundred will do so in a minute or so. Before you fall over you have to absorb enough to combine with half your haemoglobin, that is to say about 20 or 30 cubic inches. This takes some time, as you only absorb about half the quantity breathed in. So it is quite safe to take a sniff even of the pure gas.

A small warm-blooded animal such as a mouse or canary uses up about twenty times as much oxygen per unit weight as a man. It needs this to keep warm. So it also absorbs carbon monoxide twenty times as quickly. My father found that in air containing dangerous quantities of carbon monoxide birds fell off their perches long before he felt anything, though he was affected in the long run. So he introduced the use of birds as indicators for carbon monoxide after colliery explosions. The miners did not at first understand the principle involved, and a Northumberland miner gave the following account of Blackett, one of the first mining engineers to use it: "When he goes down the pit he takes a bird, and it's a parrot; and it walks in front of him and says, 'Blackett, thou bloody fool, come on' ".

A small cage bird would certainly be of some value against carbon monoxide poisoning in shelters. Though a budgerigar would not be quite as useful as a canary or a linnet. But a bird would give no warning if the people in the shelter were asleep, as it does not suffer, but falls quietly off its perch.

Actually the danger of carbon monoxide poisoning is a very minor one compared to that of airborne diseases such as diphtheria and cerebrospinal meningitis in crowded and unventilated shelters. And as winter comes on pneumonia will be added to the list.

These are part of the price which the people have to pay for Sir John Anderson's refusal to allow the construction of shelters where they could sleep under moderately hygienical conditions. His "experts" told him that people would not go a hundred yards to reach a shelter at night. The people have voted with their feet, as Lenin put it, against the experts.* They need sleep, and cannot get it above ground. But a good many of them, especially of children, will die of disease unless they can get more and better ventilated shelters very quickly.

Note

Mr. McCloskey, of 30 Gibson Square, Islington, has taken me to task for this statement in a very interesting letter. He went to bed with the gas-fire on, and was awakened by the exaggerated beating of his heart. He had the greatest difficulty in getting out of bed, and felt ill for some days. On another occasion when he entered a bathroom where a boy had been partially poisoned by a defective geyser, his heart "began to kick out". On the basis of these experiences he writes, "As a detector of carbon monoxide I am prepared to compete with a mouse or canary. Any weight or age!"

In spite of this, I should bet on the canary in some circumstances. But I was wrong in saying that CO gives no preliminary warning. If they are on the lookout for symptoms, most people will notice something, though probably few hearts react as strongly as Mr. McCloskey's. Certainly a great many people have died of CO poisoning in sleep without being awakened. And I think my heart beats quite as violently after a near miss by a bomb during an air raid as it does with a little CO. The correct statement would be that CO gives such slight preliminary warning that it may not be noticed, particularly during hard work, danger, or sleep.

Will Hitler use Gas?

DURING this spring[1] we have had a good deal of British official propaganda concerning gas protection. This may have been based on genuine information, or on reports from "intelligence" agents who, as so often in the past, have been completely deceived concerning Hitler's intentions.

The following weapons are included under the term "gas":

(1) "Non-persistent" gas such as phosgene, compressed into a liquid which is dropped in bombs which release it very quickly on hitting the ground. Such gases are deadly, but soon dissipate except in a dead calm.

(2) Liquids giving off a poisonous vapour, such as the "persistent" mustard gas. They could be dropped in small containers, or sprayed from planes. They do not kill so quickly as the first class, but the liquids contaminate areas for a long time.

(3) Powders which give off a poisonous gas on wetting, or more slowly on contact with moist air; such as calcium arsenide, which gives off arsine.

(4) Smokes produced by special apparatus. They are not so poisonous as the gases, but intensely irritating, and may make people tear off their masks.

The civilian respirator, if not damaged, and if properly fitted, gives excellent protection against (1) and (2), fair against (4) and partial against (3).

We can be nearly sure that a gas attack will be made at night, since large daytime raids are costly to the Germans. We can also surmise that the first one will be on a very large scale, to take advantage of the effect of surprise. Suppose a gas attack were made on a small town, and killed several hundred people, the whole population of the larger towns would begin to carry their masks, and most of them would get them inspected. So a subsequent attack on a large city would be far less effective. The heaviest immediate casualties would be caused if it were made during the rush hour when people are going to and from work. On the other hand if it were made about midnight or later, the difficulty of warning people and evacuating contaminated areas would be greatest. Finally in summer the ground is often warmer than the air, so that there are ascending air currents which dissipate a gas cloud. And mustard liquid evaporates quicker, so that a town would not be contaminated for so long, though the danger would be rather greater at first.

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[1] 1941.

All these arguments favour a gas attack in winter if at all. The following are possible grounds for an attack in summer. (1) An invasion. The enemy might try to disorganize troop movements by contaminating London and important road and railway junctions with persistent gas. (2) Desperation. Hitler will not scruple to use gas as a knock-out blow before giving in, if things go badly for him. (3) If the various discontents of different people are canalized into a demand for a sell-out, Hitler may wish to intensify it by a big gas attack. Hess probably believed that there was big support for a sell-out in the British ruling class. If Hitler shares this view, he may order a gas attack when he thinks the situation is politically favourable. (4) If it is generally believed that a gas attack is only possible in winter, he may make it in summer for the sake of surprise.

On a balance, I think a gas-attack is a good deal more likely in winter than summer. But it is possible at any time, though unlikely when there is a high wind, and very unlikely except on big towns or vital traffic centres.

Here are some measures which should be taken before winter:

(1) Compulsory inspection of all civilian respirators, and compulsory tests of them in an atmosphere of tear gas. Many of them have developed holes, and many others have never been properly fitted.
(2) Tests on respirators for protection against arsine. This gas is not so deadly as some others, but even a small

concentration causes jaundice after some hours. If the tests are not satisfactory, proper filters should be added.[1] If they are satisfactory, the public should be told. Owing to the distrust of British Government experts which has resulted from public experience of shelters, it would be worth calling in an American expert.

(3) Proper instructions to the public. The official leaflet tells us to put our hands in our pockets. What about women in summer clothes? It tells us to shut our windows. What happens if they are broken? It tells us nothing about how to work a baby's protective helmet. What happens if the mother becomes a casualty?

(4) Gas-proofing of shelters. I know that some of the existing shelters cannot be made gas-proof. That is another argument for shelters of one of the types that I have recommended, which can be made gas-proof.

(5) Arrangements for rapid evacuation of contaminated areas, preferably by fleets of motor buses, with arrangements for food and shelter in the reception areas.

Unless these things are done, a gas attack will mean heavy and unnecessary casualties. Nevertheless let me end on a more cheerful note. I have been hit by a bomb splinter. I have also been sufficiently gassed to send me to bed. I much prefer the latter. I always carry a respirator in a large town at night. And personally I would very much sooner spend a night in London during a gas attack than during a heavy blitz with no adequate shelter to protect me.

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[1] They have been since this was written.

The Physiology of Flying

IN a modern war, men are not merely exposed to bullets, bombs, shells, and so on. They are put for many hours under utterly abnormal physiological conditions. Think, for example, of men shut up in a submarine lying on the bottom in enemy waters during the whole hours of daylight, or exposed to the heat, noise, and shaking of a tank.

The most widely studied of all these physiological dangers are those which threaten the airman. On their first flight almost everyone notices pain or discomfort in the ears while descending. This is because there is a greater air pressure outside the eardrums than inside them. It is easy to adjust the pressure inside by blowing the nose, and pilots soon learn to do it by swallowing, or even without thinking at all.

The first serious effects of the low atmospheric pressure come on at about 10,000 feet, and get worse fairly quickly. They are due to want of oxygen. At 10,000 feet the barometer reads about 22 inches instead of 30, and at each breath the pilot gets only 74 per cent of the amount of oxygen that he gets at ground level. He probably does not notice any bad effects. Indeed he may feel rather cheery. But, like the man who has had a couple of pints of beer, he is not so efficient as before. He will take a little longer to work his controls, and score fewer bull's eyes when shooting. So he must start breathing oxygen, or rather adding oxygen to the air which he breathes.

I do not know, nor should I publish it if I did, at what height oxygen breathing is compulsory. But it is very dangerous for a pilot to wait to breathe oxygen till he feels that he needs it. I have felt quite normal at a low pressure, but yet when I breathed oxygen the light seemed suddenly to brighten, and sounds got louder.

At about 37,000 feet the air pressure is one-fifth of an atmosphere, and even if you breathe pure oxygen, you get no more than in air at ground level. However, some pilots can stand oxygen want better than others, and can go a small distance higher without danger. The ability to do so can be tested in a low pressure chamber at ground level, and can to some extent be developed by training.

At still greater heights it is necessary to breathe oxygen under a pressure greater than that of the air around the plane, though less than at ground pressure. If one tried to breathe compressed oxygen from a cylinder the lungs would burst, so to prevent this the pressure round the body must be nearly the same as inside the lungs. This can be achieved in two ways. The cabin may be made airtight, and kept full of relatively compressed air, as in the German Junkers 86 reconnaissance plane. This adds to the plane's weight, and the air will soon leak out if the cabin is hit by a bullet, let alone a shell. Or the crew may wear pressure suits somewhat like diving dresses, and containing oxygen under pressure. This type of suit was invented by my father, and will presumably be used by the first men to land on the moon, where there is no air at all. But a pressure suit inevitably hampers an airman's movements, and is less popular than a pressure cabin at present.

One striking effect of oxygen want is on night vision. We all know that it takes about half an hour to see as well as possible in the black-out. Efficient night vision is a physiological feat which needs the proper chemical conditions. One is a good supply of vitamin A. Another is plenty of oxygen. Wald, Harper, Goodman, and Krieger of Harvard University, have recently shown that night vision is one of the first functions to be affected by mild oxygen want even at heights as small as one mile. So a good oxygen supply is particularly necessary for night fighters and bombers.

Even with oxygen, there is another danger at great heights. This is the condition first observed in divers and compressed-air workers, called "bends". The commonest symptom is pain in the joints, which may prevent one straightening the limbs. It is due to bubbles of nitrogen in the joints, marrow, or spinal cord. If a diver has been under 100 feet of water, and therefore breathing air at 4 atmospheres' pressure, and comes up too quickly, the nitrogen which has dissolved in his tissues under pressure forms bubbles. Similarly if an airman flies up too quickly to a pressure of a quarter of an atmosphere, that is to say 33,000 feet, he is liable to fizz a bit.

On November 22 a Sunday newspaper had the following sob paragraph: "No-one who has ever gone through an attack of the bends has been able adequately to describe his suffering. It is an excruciating pain in the joints, shoulders, elbows, knees, ankles. It leaves the victim in a state of nervous collapse." If the *Daily Worker* had ever published this absurd exaggeration, there would have been a good case for suppressing it for creating alarm and despondency in the R.A.F. I have had bends both from high and low pressure, and the pain was never bad enough to stop me eating, let alone to make me sweat, which I take as a good rough sign of severe pain. It is usually no worse than rheumatism, and rather like it. We even had trouble in one series of experiments concerned with escape from submarines because some of the subjects (not all of them communist party members) wouldn't admit they had bends.

A discussion of what airmen can do to avoid bends would take us a little too near to the Official Secrets Act. Nor can I discuss what has been done to combat the tendency to faint when turning rapidly or coming out of a nose-dive. In this case the blood which ought to be going to the head is swung into the legs and belly. And there are other physiological problems of flying which cannot be written about at all just yet.

These problems are being tackled with fair success. The men who are doing it are well fitted to tackle problems of industrial health which are as important in peace as in war. If the Trade Unions take the matter up the men will be available for the necessary research. The Soviet Union is far ahead of us in work on the physiology of industrial work. Here is another field in which we could learn from our great ally.

"G"

COULD a man live on the planet Jupiter? This sounds a very remote question, but the answer to it happens to be pretty important to the R.A.F.

Not that they are going to fly there, for our planet's air thins out so quickly as you rise, that there is little prospect of a plane going even 25 miles up in our lifetime. And Jupiter is nearly 400 million miles away when nearest to us. But the pilots and crews, particularly of fighters and dive-bombers, have to face one condition which is abnormal on earth, but normal on Jupiter, namely an extra force on their body due to acceleration or gravitation.

Jupiter is much larger than the earth. It weighs 318 times as much, as we know from the fact that its satellites have to move much faster than our moon to avoid falling. Its surface is hidden by clouds, dust, or smoke, as we can see from the constant changes in its markings. It is also intensely cold, and the atmosphere would be poisonous to men, as it contains ammonia. But the atmosphere is very thick; so a rocket from the earth would be slowed down before it hit the surface, and landing would be easier than on Mars, let alone the moon.

The cold and gases could be kept out with something like a diving dress or even an armoured tank. But nothing will keep out gravitation. Even at the top of the cloud layer gravitation is nearly three times as strong as on earth; at the planet's surface it may be four or five times. That is to say 1 lb. weight would register at least 3 lbs. on a spring balance. And a man weighing 150 lbs. would have to support an extra weight of 300 lbs. or more if he stood up.

In fact he would be subjected to the same forces as a pilot flattening out after a dive, or pulling up suddenly from fast horizontal flight. In either case the pilot undergoes a big acceleration, that is to say a change of speed. Now speed by itself has no effect on men, or on anything else. We can only detect speed by watching what we pass. In a closed box speed cannot be measured or detected. But a change of speed can. For example a plumb line in a railway compartment does not hang vertically if the train is speeding up or slowing down. In the first case the bob is left behind, in the second it tends to go on with its original speed, and therefore the plumb line slopes forward. In either case a spring balance would show an extra force on the line added to the weight of the bob. Similarly if the train goes round a curve there is an extra force called centrifugal force swinging the bob outwards.

Einstein's general theory of relativity states that there is no way of distinguishing between forces due to acceleration and gravitation. No-one who has understood the first third of Engels' *Antidühring* should have much difficulty in following Einstein's main ideas, though of course his mathematics are no joke.

The extra force on a pilot may be very great. It is generally measured in "G". If it is in the same direction as gravity but four times as great, we say the pilot is subjected to 5 G's. If a Spitfire or Stuka pilot were sitting in the normal position as he flattened out from a vertical dive at 250 m.p.h. he would press down on his seat with perhaps twenty times his normal weight, or with 20 G's. Figures for these machines have not been published, but as early as 1931 American fighter pilots were subject to as much as 9 G's, and this must now be greatly exceeded. If the centrifugal force acts from head to feet, the pilot's blood cannot return to the heart from the legs and belly.

The heart goes on beating as long as it has any blood to pump, but after a time which may be as long as 10 seconds it runs dry, and the brain gets no blood. There is a sudden "black-out". The pilot goes temporarily blind, and may lose consciousness. This is almost certainly fatal if he has just come out of a vertical dive and is skimming the roof tops.

Things are even worse if centrifugal force sends the pilot's blood into his head. This happens if a sitting pilot suddenly goes into a dive at high speed. The head feels as if it would burst, everything goes red, and there is violent headache, and confusion which may last for several hours, even after an acceleration of even 3 or 4 G's. Whereas after the blood has been drained into the legs the pilot recovers consciousness within a few seconds, and unless his machine has crashed, is normal within a minute.

There are similar dangers during "baling out" with a parachute. When the parachute opens the pilot's speed is violently reduced, and his blood may rush to the head or feet. Curiously enough there is no danger in an ordinary fall. A man cannot fall at more than about 120 m.p.h., as at this speed the air resistance balances his weight. So an airman can fall for as long as a minute, and open his parachute without danger. But if he jumps from a plane going at 300 m.p.h. and opens his parachute at once he may quite well be killed by the shock. He actually slows down as he falls, and must wait till he has done so.

Of course steps are taken to deal with these dangers. It is no secret that in certain types of aircraft the pilot is not in a sitting position. Nor is it a secret that American pilots before the war were using rubber belts which could be inflated to press on the belly to prevent blood flowing into it. No doubt this article is out of date—laughably so, I hope, to readers in the R.A.F.

But it shows why every air force needs the service of first-rate physiologists as well as ordinary doctors, and incidentally it makes it probable that men could live on the planet Jupiter. But they would have to spend most of their time crawling. So I for one, do not greatly regret that I shall be dead long before I have a chance of going there.

Doodlebugs

THE latest secret weapon has turned out to be a pilotless plane which is intended to fly for a definite distance in a specified direction, and then dive to the ground with a cargo of high explosive.

If such a plane is launched from a place in the Pas de Calais 100 miles from London, and its errors in direction and range are only 1 per cent, it will fall within a mile of its mark. For example, if the planes are aimed at the Government Offices in London, they will all burst within a mile or so of Whitehall. It is, of course, an official secret whether they are as well aimed as this. If so, it does not compare very well with the aim of a rifle. A very indifferent marksman can hit a target, two yards across and a hundred yards away, every time. Even if almost every plane gets within a mile, this is no better than an archer could do seven hundred years ago without any sights. Otherwise, it is a good deal worse.

A plane can be kept on its course in several ways. So far as I know the only way of keeping a plane on its course relative to the earth's surface is by radio. But two can play at that game, and doubtless our radio experts are prepared to jam any guidance of this kind. Personally I should bet about three to one that these planes are not radio controlled.

By means of a gyro-compass a plane's nose can be kept pointing in a given direction. But on account of the wind it will not fly exactly in this direction. No doubt before the plane is launched, its course is set so as to make allowance for the wind. But this has two disadvantages. The direction and speed of the wind are not the same over London as over Calais.

And the plane's speed is not constant either. Suppose the plane's speed is 250 m.p.h. and it is meant to fly north-west, but there is a side wind of 25 m.p.h. blowing from the north-east, it must be aimed about 10 miles north-east of a target 100 miles off. But if the side wind drops to 10 m.p.h. it will be 6 miles out from its target. Similarly if the plane's speed falls to 200 m.p.h. the wind will have a greater effect on it, and it will go about 2½ miles to the left of its target. Presumably it is set to dive for the ground after it has gone a certain distance. But actually it dives on the alarm-clock principle, after it has flown for a certain time. Now this means that a change in its speed will have a far greater effect on its range than its line. For example, a drop of speed from 250 to 200 m.p.h. would mean that the plane dived 20 miles short of its target 100 miles away.

It is fairly easy to regulate the speed of a plane automatically by a throttle. But this means that it can never fly at the maximum speed possible for its engine, and is therefore an easier target for gunners on the ground or in the air, besides having a greater lateral error from wind. So I should guess (whether rightly or not I don't know) that the error in range was a good deal greater than that in line. That is to say supposing planes are aimed at a given town, they are more likely to fall 10 miles short or over it than 10 miles to the right or left. No doubt our Staff knows by now whether this is so.

Similarly the height can be regulated by an aneroid barometer, so that if it rises, and the pressure falls, the vertical rudder in the tail is lowered to make it fall again. This is all very well if it is flying at several thousand feet. But if it is flying low to dodge our fighters and flak, a fall of a tenth of an inch in the barometer between France and England will force it down 100 feet.

The design of instruments for automatic control is extremely tricky. If they answer too well, a deviation of say 100 feet upwards is answered by a swerve 200 feet downwards, and so on till control is lost. If they answer too slowly, large errors of course may accumulate. Essentially the same problem occurs in the automatic control of the temperature of a furnace or the speed of a dynamo. These problems can be answered roughly by calculation. But it is a curious fact that where great accuracy is needed we have to use a special type of calculating machine called a differential analyser.

The ideal pilotless plane would automatically dodge out of its course from time to time, and come back to it again. Perhaps the sound of anti-aircraft guns would automatically cause it to do so. Fortunately the German inventors have not been able to achieve this, but it may well be possible in future wars, if we allow them to happen.

So long as a plane flies in a straight line at a fairly steady speed, its position half a minute hence can be predicted. The success of our anti-aircraft guns in bringing down a large proportion of the pilotless planes depends on the efficiency of the predictors, which do the equivalent of several hours' calculation in a fraction of a second. The predictor is of much less value against piloted planes, which can take evasive action, though a dense barrage will bring them down. Today your life depends, more than ever before, on the efficiency of the craftsmen who make the predictors, and the girls who work them.

There are two morals to be drawn from all this. One is that if we had started the second front last year we should not now be being bombed by robots. The other is that if automatic machines can do a pilot's job, they can also do other dangerous or unhealthy jobs, such as mining and furnace stoking. It is up to the workers in dangerous trades to see that their jobs are ultimately taken over by machines. Underground gasification of coal as a substitute for coal mining should be the peace-time equivalent of the robot pilots, and may save more lives than will be lost in the present series of air raids.

NOTE

This article was written in the first fortnight of the doodlebug raids, and was heavily censored. I give it exactly as written. It was of course wrong in some details, but the fundamental question of accuracy of aim was not dealt with in the official statements, and is of considerable interest.

Blast

MR. CHURCHILL tells us that many of the casualties caused by the flying bombs in London are due to blast. This is not as helpful as it might be, because most of us do not know what blast is, or how to avoid its effects.

A great deal is known about blast, partly as a result of experiments carried out by the research department of the Ministry of Home Security. But these results are not available to the public. This is partly, no doubt, to keep information from the enemy, and partly to prevent the public from asking awkward questions. But it also arises from a real contempt for the public, who are regarded as uneducated. And yet there are hundreds of thousands of British people who know more physics than all but one of the Cabinet, or the vast majority of higher-grade Civil servants. Technical school physics is rather one-sided, but it is vastly better than what most boys learn at "public" schools. Owing to this official policy my account of blast will certainly be incomplete, and probably inaccurate in several respects. But it is the best I can give with the knowledge at present available to the public.

Blast is the word used to describe sudden and violent changes of air pressure. When the charge in a bomb explodes, it is converted within less than a hundredth of a second into very hot gas under enormous pressure. It expands until it occupies somewhat over ten thousand times the volume of the solid explosive. The total energy developed is not ten times as much as when the same weight of water is converted into steam, but it is let loose in a far shorter time. However, the actual amount of bricks and mortar moved, or earth scooped out, are probably no more than could be moved by a steam engine using a weight of water equal to that of the explosive.

The hot gas from the explosive pushes the air away from it. Some people who have watched a flying bomb bursting half a mile or so away have seen a flash of flame rapidly cooling into smoke, and a dark circle around it rapidly spreading upwards and outwards. This is the blast wave. It consists of air compressed to 10 or 20 atmospheres' pressure and moving at about 1500 feet per second, that is to say about 40 per cent faster than ordinary sound. In this rapidly moving shell of air the pressure is therefore at least 10 atmospheres, and is about twice as great on an obstacle facing it, because the air in the blast wave is moving, and generates pressure when stopped.

Fortunately the high pressure only lasts for about one two-hundredth of a second, for it exerts a pressure of about 20 tons per square foot, and would knock down any building if it lasted for even as long as a second. Behind the high pressure wave comes a wave of suction, or low pressure, lasting for about five times as long as the pressure wave. This is usually followed by a much smaller pressure wave. So windows which are smashed by the high pressure are often sucked out by the low pressure, which also turns corners more easily than the high pressure wave.

If an object is fairly elastic, so that it can yield to the pressure and spring back, it is little damaged. It is amazing how little harm is done to trees quite near a flying bomb, even if their leaves are torn off. The same is true of buildings with a steel frame, Anderson shelters, and surface shelters with adequate steel reinforcement.

Many of the human casualties are due to people being crushed or hit by flying bricks, stones, glass, or woodwork, or to their being knocked over by blast. But blast can kill people directly. A pressure of 10 atmospheres is harmless. I have often been exposed to it in diving experiments. But it took me four minutes or more to reach this pressure, and the pressure had plenty of time to equalise itself gradually in all parts of my body.

What happens when the pressure rises to 10 atmospheres in a thousandth of a second was worked out by Professor Zuckerman, of Birmingham, from a comparison of animal experiments with post-mortem examination of human air-raid casualties.

The blast wave in the air goes on as a pressure wave through the body until it reaches a cavity containing air. The ear-drums may be burst, causing deafness, but they generally heal completely. The effects are much more serious in the lungs, or in the intestines, if they contain bubbles. The human flesh behaves like a row of marbles touching one another in a groove. If you tap one end, the marble at the other end flies off, though the intervening ones hardly move. In the same way the delicate lining membranes of the lung or gut are torn when the wave finds nothing but air in front of it.

So a man near a bursting bomb may have no obvious injuries, but start coughing up blood and die within a few hours. If he recovers, he seems to do so completely. Zuckerman found that rabbits could be protected from blast by Sorbo rubber jackets round their chests. Thus thick clothes are some protection. But shelter is vastly more so. Blast does not turn corners readily, and even a wooden door will take up most of the force of the wave. So if you can get into a corridor or under the stairs the air wave is unlikely to hurt you.

After the pressure wave has travelled some way, it is converted into a train of ordinary sound waves. Much the same happens if a stone is dropped into a pond. It first forces the water down. Then some water rises above the original level. But a few feet from the splash we see a series of periodic waves spreading out in circles. These sound waves will set anything in motion if its natural period of vibration is the same as their own. This is one reason why some panes of glass, but not others, are broken at a considerable distance from a burst. Another is that the sound may be concentrated by reflection from walls, flat ground, or water. Physicists could learn a lot from a detailed study of such effects, if they were not too busy on urgent war research. The actual result is likely to be political rather than scientific.

The Nazi policy has been to kill civilians, including children, all over Europe, to weaken other nations in preparation for their next aggressive war. As a result of this policy very drastic measures have been proposed to make such a war impossible. Some of these proposals have met opposition in England. They will meet less now. The flying bombs and the long-range rockets, if they are used, will certainly not lose us the war. They may very well cause Germany to lose East Prussia.

Probability in War and Peace

IN ordinary life we aim at complete security. We are not satisfied that railway bridges should be so designed that 99 per cent, or even 99·99 per cent of them should stand up to the weight of a train. We aim at 100 per cent safety, though we do not get it, because railway bridges sometimes collapse, but the chance of a collapse is much less than one in a million. However, in war one has to take chances. In modern war we are at last beginning to reckon them scientifically. In fact at the present time I am engaged on calculating certain probabilities for one of the services a little more accurately than has been done before.

Naturally I cannot write about this particular calculation, but I can write about the kind of way in which chances are worked out. If a warship is firing at extreme range, the shell may drop too near or too far, and to right or left of the target. This is partly through errors of sighting or ranging, partly through errors in estimating the relative motion of the ship which is firing and the target, and partly because the ship aimed at may change her course. Besides this, the wind must be allowed for, not to mention the wear of the guns; the cordite may be slightly variable, and so on.

In shooting at an ordinary target, one is about as likely to be a foot out from the bull's-eye above or below, to right or to left. In long-distance naval gunnery this is probably not so. I should guess that errors in range were apt to be bigger than errors in line. Anyway one group of errors must, on the average, be larger than the other.

Let us see what this means. If errors in all directions are equally likely, which is roughly true in rifle shooting and in bombing with certain techniques, then we can represent different degrees of accuracy by circles, as on an ordinary target. This is fairly obvious. But it is not in the least obvious that if 25 per cent of the bullets hit within 1 foot of the mark, 50 per cent will be within 1·57 feet, and 75 per cent within 2·18 feet.

This is a result of the advanced theory of probability, and is pretty well borne out by experience. If, however, errors in range are greater than errors in line, the circles must be replaced by ellipses.

In a naval battle it may be more important to be sure of hitting an enemy ship at least once than to have a sporting chance of hitting it with half a dozen shells in a salvo. This is particularly so with a force which has numerical superiority, and can expect to beat the enemy if they can slow him down. So the different guns of a battleship's main armaments are not all aimed at the same point, but so that the shells will fall in a pattern. The calculation of this pattern is a very intricate problem, depending on the accuracy of aim in range and line, the size of the target, and so on. Presumably it has been fully solved. If not, we are wasting shells and lives.

In different circumstances it may be more important to administer a knock-out with half a dozen shells, even if the chance of this is a good deal less than the chance of a single hit. In this case the different guns must be aimed at or near the same point.

In the same way I presume that we use the theory of probability in defence, for example, in the design of minefields on land and sea. One can calculate the probability that a ship, a man, or a tank can get through a minefield, and make this as small as possible with a given amount of material.

After the war a good many people, though not enough, will have learned to think in terms of probability. This is important, because even in peace time the most important things of all are matters of probability, not of certainty. You can never be sure that you will not die before you get home, or that when you do you will not find that your wife has gone mad or your child been run over. Society should be organized so as to make such events as these as unlikely as possible. It is a striking fact that in the Soviet Union the theory of probability plays a big part in planning. Moreover, Soviet mathematicians are paying special attention to its mathematical foundations.

Only in a very few industries under capitalism is there enough planning to make it worth while to apply such notions. One of them is the telephone system. The American trust which runs many telephones has investigated the probability that an exchange will be so overwhelmed with calls by pure chance as to lose time. For though there are peak hours for calls, most calls are more or less at random, and if too many are made at once, there will be delay. The *Bell System Technical Journal* has therefore published highly complicated calculations on this question.

In a planned society transport, industry, and distribution would be designed so as to avoid not only accidents, but jamming of the machinery in this way. As things are we are faced with an alternative between monopolism on the one hand, and on the other a chaotic system with a large element of luck which gives the speculator his chance.

The insurance companies employ the theory of probability on a large scale. No-one knows who will die next year, but the number who will do so, and its probable fluctuations, are pretty well known, and rates can be fixed to insure a profit for the shareholders on any likely contingency. Thus air raids may kill an unexpected number of people whose lives are insured. But if they also kill old people who are drawing annuities, the insurance companies will not lose any money. The larger the population with which you are dealing, the greater is the degree of certainty with which you can apply the theory of probability. This is one reason why the state should take over insurance, in accordance with the Beveridge scheme or some more Socialistic plan. Another reason is, of course, the great economy which would be effected by cutting out canvassing and collecting, which would mean that the existing staff of insurance officials could serve many more people than at present.

The theory of probability is as important a tool in peace as in war. It is up to us to see that it is used.

Ice Ages and Modern History

BY the time this article is in print, the Red Army should be fighting its way through the lakes of East Prussia. In 1914 these lakes were of great defensive value to the Germans, and a large Russian army was surrounded and wiped out at Tannenberg in the lake district.

Things are different today for three reasons. The leaders of the Red Army are tried in modern war, whereas General Samsonov, who was defeated at Tannenberg, had previously been governor of Turkestan, a policeman rather than a soldier. The Red Army personnel are literate and trained to use initiative, whereas few Tsarist soldiers could read a book, let alone a map, and they were not encouraged to think for themselves.

Finally the Red Army has experience of forcing water lines such as the Dnieper. And above all, it has just fought a successful campaign against the Finns in lake-dotted country very similar to that of East Prussia. I have little doubt that specialists in this kind of fighting have been moved from Finland to the East Prussia front.

East Prussia and Finland are full of small lakes for the same reason. The landscapes of both countries have been formed by the recent action of ice. Lakes can be formed in at least four ways. Some are formed by earth movements. For example Lake Tanganyika and the Dead Sea were made by actual sinking of rock masses. Such lakes are often large and deep.

Others are formed when a river is dammed by earth brought down by a side-stream, a glacier, or an avalanche. These are generally small, and do not last long. Some are formed because the rock or soil beneath them has been dissolved. Such are the meres in the Cheshire salt country.

But in Europe the most important agent of lake formation has been ice. Lake Windermere, between Lancashire and Westmoreland, is a typical glacial lake. Before the last series of ice ages its site was almost certainly occupied by a narrow valley cut through rocks by water. When the weather got colder, the Cambrian mountains were covered with snow which solidified to ice, and crept slowly down the valleys.

A glacier only moves a few inches per hour, so it is far broader and deeper than a river draining the same area. It therefore scoops out a broad U-shaped valley. And as it may be hundreds of yards deep, it may grind away rocks to a great depth.

This happened at Windermere, which is over 200 feet deep; and its bottom is actually below sea-level in places. As we go down the lake towards the sea the bottom actually rises, for the ice was thicker and had longer to act in the "upper" part of the basin.

The barrier at the bottom of Windermere consists of rock overlaid by stones, gravel, and clay brought down by the glacier. A river can carry mud and even gravel, but only a mountain torrent can move boulders, while ice can carry them for hundreds of miles, and dump them when it melts.

The mounds of clay and stone deposited at the foot of a glacier are called moraines, and once you have seen them actually being made in the Alps, it is easy enough to recognize them in England. The lower end of Windermere is dammed by a moraine. So ice not only scooped out the basin, but increased its depth by carrying down sediment in a way which water could not do.

Some of the Finnish lakes were formed by this double action of ice. But many in Finland, and all in East Prussia, were made by the carrying rather than the scooping action of glaciers.

Thirty thousand years ago a huge icefield covered Scandinavia and Finland, as one now covers Greenland. The ice crept away from the centre in all directions. Westward-moving glaciers scooped out the fjords of Norway. The main mass moved southward across the Baltic, which was a sea of ice, and ended in northern Germany.

Here it formed moraines which are now irregular ranges of hills. Where the border of the ice was stationary for some time these hills may reach a height of 1000 feet, though few are over 500. Where the ice melted quickly as the weather improved after the ice age, the ground level is lower.

It is here that the lakes were formed. Conditions were rather similar across the Atlantic where the ice from Canada came as far as New York. The Great Lakes roughly correspond to the Baltic, and there are hundreds of small lakes in the northern part of New York State.

The formation of the Baltic moraines had another important consequence. Poland and northern Germany mostly drain into the Baltic. But there are only two rivers which have broken through the moraines, namely the Vistula and Oder. The moraines have diverted the Elbe into the Atlantic.

In consequence a number of rivers, including the Narew, Vistula, Warta, and Elbe run westward over much of their course, and slope so gently that they can be navigated without locks, and canals can fairly easily be dug from one to the other.

Berlin is at the hub of this system of waterways, and in consequence grew very rapidly during the 18th century. This was most unfortunate for Germany, for other cities which grew more slowly had either been completely independent like Hamburg, or had at least been cultural centres for some time, whereas Berlin was the creation of the margraves of Brandenburg whose descendants became kings of Prussia.

If Hamburg, Dresden, Weimar, or Cologne had become the capital of Germany, the worship of war might be much less firmly rooted there than is the case at present. The facts of physical geography may have been more important in shaping German militarism than the inherited characters of the Germans.

It was fortunate for England and for the world that London, a great commercial city which sided against the kings in the Great Rebellion, and as late as the time of Wilkes, became our capital, rather than Windsor, York, Winchester, or Oxford. Physical geography is only one of many influences which mould the fate of nations, but it is an important one.

Coral Reefs

THE American navy, army, and air force are now driving the Japanese out of the Gilbert and Marshall groups of islands, and their bombers have attacked the Caroline group. These islands are largely built of coral, which is formed by animals like small sea anemones. Millions of them are constantly laying down new layers on the foundations laid by their parents. This rock is generally a grey or yellowish limestone. Only a few species make red or black coral.

Though a few corals occur round England, those which form large reefs can only live in warm water. The nearest large growth of living corals to England is on the Algerian coast, and the nearest easily accessible coral reef is in the Canary islands. But the climate of our country has been much warmer in the past, and some of the hills near Oxford were originally coral reefs.

When conditions are favourable for the coral-forming animals, they may make huge quantities of rock. They live best in surf, and are killed off by mud, silt, or sand. So whereas in England a wave-beaten shore where no sand or silt is being laid down is generally eaten away by the sea, it may be a place where the land grows in the tropics. There are three main types of coral reef. Fringing reefs are parts of the shore of a continent or island covered with coral rock, growing at its seaward edge. Barrier reefs, generally covered at high tide but partly exposed at low tide, lie some distance from the shore of a continent or island, with a shallow lagoon between the reef and the shore. Atolls are ring-shaped islands of coral only rising a few feet above sea-level, with a lagoon in the middle.

The main Caroline islands, including Truk, are mountainous, and surrounded by a barrier reef some miles out. This forms a breakwater which makes them into a natural naval base. They will be very hard to invade because the entrances through the reef can be commanded by guns on the high islands inside it. So far the Americans have flown over the barrier, but have not tried to get ships through it. The Marshall and Gilbert islands are mostly atolls, and are much harder to defend, since ships can approach them closely. By the time this article is printed, most of them will probably be in American possession.

Besides the coral-making animals, coral reefs have a special fauna of fishes, worms, and other creatures, which has been a joy to naturalists. The fish are generally brightly coloured, and often have cutting teeth like a parrot's beak with which they can gnaw the coral to get at the animals imbedded in it.

Darwin was not content with studying the existing condition of coral islands. He tried to understand how they had originated. Indeed he could not study anything without inquiring into its history, which was why Marx wished to dedicate *Capital* to him.

Darwin thought that barrier reefs were formed when a coast-line was slowly sinking. As the coral can only form new rock at its outer edge, this will keep up to sea-level, while a lagoon forms inside. If the central island sinks altogether, a ring-shaped reef will be left behind. If this is broad enough, broken fragments of coral will be piled up above sea-level, and a chain of low islands will be formed.

Murray and others rejected the theory of subsidence, and thought that the lagoon was formed by the dissolving action of the sea on old coral rock. He also thought reefs could be formed at a considerable depth, and gradually built up till they reached the surface. The inner part would then die, and the growing edge form an atoll.

Recent work has brought many geologists back to a modified form of Darwin's theory of coral-reef formation, just as naturalists today are a good deal less critical of his theory of evolution than they were thirty years ago, though some revision has been necessary.

One strong piece of evidence for Darwin was provided by a bore-hole 1100 feet deep made for the Royal Society on Funafuti atoll. The coral found, even at the bottom, had been made by animals which only live in shallow water.

The main modification in Darwin's theory which is desirable is to put down reef formation to a rising of the sea rather than a sinking of the land. During the recent ice ages much of Europe, Siberia, and Canada were covered with ice which may have been several miles deep in places, as it is in Greenland today.

When this gradually melted in the course of several thousand years, the sea-level rose all over the world. So the present set-up of coral islands may be a temporary one, which has not existed at most times in the world's history.

For a vivid picture of life on these low, ring-shaped coral islands, I strongly recommend Jack London's *South Sea Tales.* There are terrific descriptions of storms sweeping right over the islands, and of British imperialism, represented by the "Moon-gleam Soap Company".

Before their discovery by Europeans the inhabitants of the Caroline Islands had reached a considerable degree of civilization, and made great stone buildings, now ruined, on artificial islands in the shallow water behind the coral reefs. Most of them were killed off by the Spaniards who conquered these islands in the 16th century, and the Germans and Japanese, who succeeded the Spaniards, did little to help them.

We may hope that those who survive the American air raids and naval bombardments may at least get a new deal, and be given a chance to live in the way which they desire, rather than according to the wishes of Jesuits or soap manufacturers.

Their fate will depend on the balance, in American politics, between imperialistic tendencies, and the more liberal policy which had promised independence to the Filipinos at a definite date, whereas the date is always omitted in similar promises to Indians. The Atlantic Charter should be applied in the Pacific Ocean.

· 6 ·

SCIENCE IN A WORLD COMMUNITY

I. A WORLD GEOLOGICAL SURVEY

IN these terrible times[1] many people will think it utopian to write sunshine stories about the future. If our Government will not even state its war aims, is it not ridiculous for members of a small minority to discuss what they hope will happen?

I don't agree. Marxists think that history is moving towards universal Socialism and the breakdown of barriers not only between classes but between nations. And one solid block of two hundred millions in the Soviet Union is working towards these goals. Not towards a world state. States are instruments which are efficient for class war and international war, and very inefficient for many other purposes. A world-wide Socialist community would probably be so different from any existing state as to deserve some quite different name.

One of the first tasks of scientists in a world organization would be a real world survey. This has so far been done in a very uneven and unorganized way, owing to rivalry between nations and firms, and to the predominance of the profit motive. There is, for example, an immense amount to find out about the geology of the British and French Empires, because there are not enough qualified British and French geologists to do the job, and foreign geologists would not be encouraged. A few Indian geologists are now studying the rocks of their country, but I have yet to hear of any Nigerian or Ugandan geologists, though members of "primitive" races in the Soviet Union are taking up geology.

A good deal of geological knowledge is a trade secret of oil and mining firms. Very little is known of the geology of some countries, for example Afghanistan and Tibet. This is largely because the Afghans and Tibetans do not think they would be any happier if oil or gold was discovered in their countries, and do not allow prospectors. If they could go to the Caucasus, they would see a country where oil has brought wealth to the people, and not to financiers in New York, London, or Amsterdam. So if they were sure that their countries' minerals would be used for their own good, they would probably change their minds.

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[1] November 1940.

The first task of world surveyors, then, would be the preparation of detailed geological and climatological maps of the world. Over wide areas nothing of economic importance would be found. But over the world as a whole enough would be discovered to increase the mineral resources of the human race many times over. This has certainly been the result of the great geological survey of the Soviet Union which is still going on. Incidentally we should gain an immense amount of new knowledge concerning evolution. For the detailed history of evolution can only be based on a study of fossil animals and plants.

It has long been clear that both mammals (that is to say warm-blooded hairy animals which suckle their young) and birds are descended from reptiles. We know many details of the origin of mammals, thanks largely to the work of one man, Broom. We know very little about birds, though a few fossil birds with teeth in their jaws, claws on their wings, and long bony tails, make the general line of their evolution clear. In South Africa the Karoo formation consists of rocks which were laid down fairly steadily during the time mammals were evolving. Elsewhere, so far, there is no continuous record, though a certain number of reptile-mammals are known. But the South African record shows that the bones and teeth at least evolved either quite steadily, as Darwin believed, or by fairly small steps. Geology has been highly developed in South Africa, because of the search for gold and diamonds. Perhaps the similar record for birds will be found in a country where there are no economically valuable minerals. The evolution of horses was mainly worked out from fossils in U.S.A. beds which were excavated on scientific rather than purely economic grounds.

A world geological survey would include some colossal engineering tasks. If we are to find out what the rocks are like in central Greenland we shall have to bore through more than a mile of ice to get a sample. It will be necessary to bore below the floor of the deep ocean at a number of points. At present we know a lot about the silt on the surface, and have taken a few samples going down ten feet below it. Presumably our descendants will lower a boring machine four miles or more in some deep but calm part of the ocean, and anchor a ship or raft above it, from which electric power will be transmitted. Only then shall we know how thick the sediments are, and whether, as many geologists think, the rock below them is generally basalt, as opposed to the granite which is usual under the continents.

Another task will be the exploration of the deep rocks under the continents. At present the deepest borehole is under three miles deep, about one fourteen-hundredth of the distance to the earth's centre. If the earth were the size of an apple, this would correspond, not even to the thickness of the skin, but to that of the waxy layer on its outside.

The rocks near the earth's surface are generally sedimentary, that is to say were slowly formed on the surface under the influence of water, wind, or ice. Under them almost everywhere, and sometimes at the surface, there is granite. But the granite layer is not very thick. About six or eight miles down, the evidence from earthquakes makes it pretty certain that the granite lies on denser rock, and below this is a still denser layer. We shall have to know what these are made of. The information may be of no economic value. But we may strike vast supplies of valuable minerals, or find out how to use the heat as a source of power.

It will only be possible to plan a world community if we know our resources. And since we can make new plants and animals, but not new minerals, a survey of the world's minerals will be needed before the world really becomes man's world.

II. A WORLD BIOLOGICAL SURVEY

Last week I dealt with the need for a survey of the world's rocks. Some critics will say that I am taking an out-of-date view of science. The 18th and early 19th centuries were the times for collections. Collection has been superseded by experiment.

I don't agree. The first real world survey of plants and animals was made by the great Swedish biologist Linnaeus, who listed all the species known to him. He got his specimens from the imperialistic voyagers of his time. The British and French merchants were struggling for the domination of India, the Spaniards and Portuguese were at last looking for something beyond gold and silver in South America. He listed the plants and animals which they found.

We shall need a survey inspired by Socialism as Linnaeus' survey and those of his successors were inspired by Imperialism. Here the "pure" scientist will hold up his hands in horror. "There is only one science," he will say; "you are going back to the Middle Ages if you speak of Socialist science, as if politics could affect truth."

On the contrary, a survey on Linnaeus' lines is very useful for the rapid exploitation of a country. It tells you where you will find a particular sort of animal or plant. But it does not tell you how to keep up the supply of it. And in consequence large tracts of the earth's surface have been devastated. Wild animal species such as the American and European bisons and one species of mountain zebra have been almost exterminated; others, like the American passenger pigeon, and the tarpan, one of the wild horse species, are dead. Many forests have been cut down, leaving bare rocky hillsides. Large areas of the central United States have turned into a dust bowl.

The modern study of wild animals and plants is a very different matter. For one thing it is quantitative. Biologists are counting plants and animals, not of course as accurately as human beings are counted at a census, but still fairly accurately. In a few cases the total number in a species in the whole world is known with fair accuracy. This is so for the big trees of California, and for two British birds, the St. Kilda wren and the gannet. When last counted these numbered 136 and 156,000 adults respectively. The number of adult herons in Britain was about 8000 in 1928 with a possible error of a few hundreds each way.

Even insects can be counted. For example tsetse flies in Africa and butterflies on one of the Scilly Islands have been counted as follows. Each day a number are caught, marked with a spot of coloured varnish, and released. The number recaptured on later days is then counted. For example if 50 butterflies are marked green on the right forewing on Monday, and out of 50 caught on Tuesday, 5 have green marks, this means that the total population is about 500. If you go on for a month you get a fairly accurate estimate of the total, whether it is increasing or not, and of the average length of life. You can also find out how far the insects usually fly in a day, and many other interesting points.

Above all, the modern naturalist studies animal and plant communities and their relations. These communities, if they are not changing, are in a state of equilibrium which is easily upset. Today in England rabbits eat a vast amount of grass which would otherwise support sheep or cattle, whilst in Australia they are a national calamity. But in the Middle Ages rabbits were quite valuable in England, especially as a source of fur, and only noblemen were allowed to have rabbit warrens on their land. They have increased, in spite of the denser human population and the use of shotguns, because hawks, foxes, weasels, stoats, and other animals which eat rabbits, have been killed off.

But a good many plant and animal associations are unstable, unless men intervene actively. Leave an English ploughed field alone, and it will soon be covered by grass. Within a generation the grass is invaded by thorns and other shrubs. Then more gradually, in most areas, trees will oust the shrubs. And in a few centuries there would be fairly dense forest, as there was two thousand years ago over much of the country. This stable plant community is called the climax, and consists of forest over most parts of the globe, though in other areas it may be desert, grassland, heath, or marsh. Of course as a plant community changes, so do the animals. As woodland replaces open country we get a completely different set of birds, which nest on trees instead of on the ground like larks. Wild pigs would replace grazing animals, squirrels would become commoner than rabbits, and so on. One of the first steps in investigating an animal community is to find what each animal eats. This involves identifying their stomach contents at different times of the year, and is a difficult job. For it is one thing to identify a whole beetle, but much harder to find the species to which a wing-case or leg belongs.

The scientific study of animal and plant communities is called ecology. It has been mainly carried out in Europe and North America. Some of the best studies have been in the Arctic, where there are rather few species of animals and plants, so relations are simpler.

Similar studies in the tropics are essential if they are to be made fit for healthy and happy human life. Irrigation may lead to a big cotton crop, and a flow of profits to the city of London. It may lead to an increase in the local population. But it may also favour mosquitoes which spread malaria, and worms which bore into men's tissues. In a planned world community the probable results of any change in agricultural methods, or of clearing forests, would be investigated before this was done on any great scale. And a systematic attack would be made on dangerous spots, such as the semi-desert areas where locust swarms breed which may fly off and devastate crops a thousand miles away.

In the same way the exploitation of the sea would be controlled. Today whales are being exterminated, and many areas grossly over-fished. But few international agreements on such matters last for long. World control of fishing and whaling would in the long run increase the sea's yield, and save valuable species from extermination. And the extinction of a species is far worse than the killing of an individual. The individual is replaced in a generation. It may take a million years to make a new species. The preservation of valuable species would be part of the task of a world community.

III. POWER

Lenin saw that Socialism could only succeed in the Soviet Union on a basis of electrification. For though the Soviet Union is rich in coal, its coal resources are probably less per unit area than those of Britain or Germany, and many districts are a long way from coal-fields.

Besides, Lenin, though he had a keen eye for the present, looked centuries ahead. And once Socialists have abolished poverty, they will inevitably plan and build for posterity rather than for immediate profit. Our mediæval ancestors, whatever their faults, built for the future, and their cathedrals, colleges and halls are among our greatest treasures. The 19th-century capitalists, with their eye on immediate profits, left very little which posterity will want to preserve, and squandered natural resources in an abominable way. A large amount of the coal of Britain is unworkable because the seams were worked without any general plan.

The problem of power falls into three divisions, namely generation, transmission, and storage. The first sources of power, apart from slaves and animals, were wind and water mills. The factories of the late 18th century were largely built over water mills. But before the invention of the dynamo water power could only be transmitted for a few hundred feet at most. And before the invention of accumulators it could not be stored. Today energy is mainly transmitted in two distinct ways. Electric power can be sent for hundreds of miles by a grid of high-tension cables, from a generating station at a source of water power or a coal-mine. Or it can be sent by rail, ship, or pipe-line, stored in the form of coal or oil.

But energy in its most readily available forms, mechanical and electrical, cannot be easily stored. Accumulators are too heavy and bulky to be of much use for driving vehicles. Any vehicle which does not run on a fixed route where electric power is available must use coal, oil, or some other chemical source of energy, generally from underground.

A world society will rely so far as possible on electric power generated by water, for a very simple reason. A waterfall does not last for ever, but it lasts for tens of thousands of years. A coal-field or an oilfield is exhausted in a century or so, and it takes millions of years to make a new one.

Tidal power as well as fresh water power will be used. This will involve the temporary storage of energy. A Socialist Government of Britain will at once start on the Severn barrage. This will give a great deal of electric power for eight hours of the day, when there is a big difference of water level on the two sides of the dam. It will give less power over another eight hours, and hardly any during a third eight hours. So the extra power of the peak period will have to be stored. It is proposed to do this by pumping sea water up into an artificial lake in the Wye valley, which will empty during the time when the tides are slack, and thus furnish a steady flow of power. This scheme was turned down twenty years ago because it would have interfered with various private interests, and would not have given a high return on the capital invested. But in a Socialist community such schemes will go forward because they will in the end form almost imperishable additions to the people's wealth.

When most of the readily available fresh and tidal water power of our planet is harnessed, and used for factories, railways, trams, trolley-buses, lighting, heating, and so on, we shall still need more power in some areas, and also a source of power for ships, aeroplanes, buses, cars, and other vehicles which do not go on fixed routes.

A very obvious further source of power is the wind, but this is so spasmodic that it could only be used if the power could be conveniently stored. There are several possibilities of doing this. One, of course, is a big improvement in accumulator design. This seems less likely now than it did twenty years ago. Another is the development of condensers. Some of the modern plastics have such a high dielectric constant that it might be possible to use them for storing static electricity at high voltages. More probable is the use of electric power to produce a fuel which would replace petrol, coal, or both.

It is fairly easy to make hydrogen by passing an electric current through a solution of an acid or salt in water. The means of liquefying it have been vastly improved by Kapitza in the U.S.S.R. But its storage is another matter. It is the lightest of all liquids, so it takes up a lot of room. And it must be insulated from heat, or it soon evaporates. Things would be vastly improved if electric power could be used to make a gas which is more easily liquefied, and less bulky, such as methane, or still better, some of the components of ordinary petrol. Liquid methane, from underground natural gas liquefied in factories, is already used for driving buses in the Soviet Union. But so far as I know no-one is tackling the problem of making it by electric power.

Such problems as this will be one of the tasks of scientists in a world community. The ultimate aim of such work will be to provide sources of power for the human race which will last indefinitely, and will not involve the danger and dirt inevitably associated with the mining and transport of coal and oil.

To a biologist the dirt is an important part of the story. Try to imagine a city where there was no smoke, and no dirtying of hands and houses with coal, but also, of course, no horse dung in the streets. Its inhabitants would take for granted a standard of cleanliness which would enable them to raise their health to a higher level.

Power would be available in vast quantities, but it would not be based on the yearly sacrifice of thousands of coal-miners, and the spoiling of vast areas of what was once beautiful countryside. The nearest approach to this ideal is found today in countries such as Switzerland, where water power is very abundant. In a properly organized world it will be the normal human environment.

IV. FOOD

In earlier articles of this series I have dealt with some of the surveys which will be needed so that the resources of our planet can be used to the best advantage. Of course plenty more will be necessary, particularly a world survey of diseases. At present many diseases are confined to a small area, from which they are liable to spread when communications are improved. Such are Rocky Mountain Spotted Fever in North America, and Oroya Fever in South America. These should be stamped out before they have spread.

But the great tasks will be those of the experimental rather than the collecting and surveying branches of science. Some of our activities, such as transport, communication, and war, involve a great deal of science, others such as feeding, clothing, and the building of ordinary houses, a great deal less. As regards food, it will be necessary, first to find out as exactly as possible what people need, secondly how to provide food with the minimum expenditure of labour, and thirdly how to make it as pleasant as possible. Of course these three tasks would go on together.

The first task would imply the use of hundreds of men, women, and children as experimental animals, kept on rigidly controlled diets, like so many rats, and with their health and growth very carefully studied. The subjects would not be likely to die, or even to become seriously ill. For the object of the research would not be to find the minimum needed to preserve life, but the minimum needed for perfect health, which is a very different matter. They would probably find their artificial diets rather dull.

The second task is a far larger one. I am prepared to bet heavily that the diet produced with the minimum labour expenditure would be a vegetarian diet, and what is more, a rigidly vegetarian one. For most so-called vegetarians consume animal products such as milk and cheese, which are made without taking animal life. However they are made by a roundabout process. The cow eats grass, and some of the foodstuffs present in the grass reappear in the cow's milk. But most of them are used for movement, for growth, for producing bull-calves which do not make milk, and so on.

Our chief classes of foodstuffs are carbohydrates such as sugar and starch, fats and oils, and proteins such as the main constituents of meat and cheese. We can easily get our starch and margarine or oil from plants, but plant proteins have so far proved less satisfactory than animal proteins for human diet. To keep in health we need far more of the proteins of bread and beans than of milk, meat, eggs, or fish. This is because the plant proteins usually eaten are those which plants store in their seeds, and not those which they use in their living cells, for the actual work of making starch, wood, and so on.

These latter are much more like the human body proteins, so we need less of them in our food. On the other hand we cannot eat leaves in large enough amounts to supply them, since we cannot digest the fibres and cell walls. A cow can do so, at least in part. So we eat our leaf proteins second-hand as beef or milk. However, we only get somewhere between a fifth and a tenth of the protein eaten by the cow. It is quite possible to extract the proteins from grass by means of a press. They are not very tasty, but seem to be quite nourishing. And the process of extracting them has reached a stage when Lord Woolton, the Minister of Food, ate some in a Cambridge College recently.

Grass protein could at present be used to replace a good deal of our meat and cheese. But I do not think that it will be so used. For one thing the National Farmers' Union would probably raise objections, and if not, some official or other would almost certainly obstruct the effort to use it. In addition most people are very conservative in their feeding habits. The workers would be justly suspicious that this grass protein was about as useful for preserving health as a brick shelter built with lime and sand instead of mortar for preserving life.

They could be induced to eat it if, for example, the Royal Family, the inhabitants of the Dorchester Hotel, and every officers' mess in the army ate grass protein instead of meat on two days of the week. When this has gone on for a month, I shall be glad to help in a campaign to spread its use among the people. While therefore I doubt whether we shall use the resources of Britain to the full in feeding ourselves during the present war, I have little doubt that some day our descendants will do so. The fibre which remains when the juice has been pressed out of the grass could be used for various purposes, including fodder and fuel, and as a substitute for wood.

I think that such a change is likely to be successful on other grounds. If people are not accustomed to violence, they dislike the idea of killing animals. I think I would become a vegetarian rather than kill all the animal meat I eat, though I am not an absolute pacifist towards animals, and will swat flies or set mouse-traps when I think it necessary. I think that a time will come when no-one will volunteer for the work of slaughtering animals, and very few will be prepared to eat them. But I do not think this will happen till we have stopped killing human beings for a century or so.

And I don't think that we shall ever adopt the attitude of some Indian religions such as the Jains, who will not kill noxious insects such as bed-bugs. On the contrary, I think one of the early tasks of the world community will be the extermination of such creatures.

It would be much harder to use sea plants directly. Most seaweeds are unsuited for human food, and once we get away from shallow water almost all the plants in the sea are microscopic, consisting of a single cell. We don't even eat them at second-hand when we eat fish.

On the contrary, a typical food-chain in the sea is rather long. Thus we eat cod, which has eaten (among other things) herrings, which have eaten small crustaceans which have eaten one-celled plants. So in this case we eat the plants at fourth-hand.

Our exploitation of the sea is at present at the primitive hunting stage which our ancestors gave up thousands of years ago. Our descendants may catch the tiny plants directly in very fine nets. They may even learn to farm the sea. We can't see how this would be done. But a primitive hunter could not imagine how to grow wheat or potatoes, so our successors may solve this problem.

In any case it is certain that by applying really scientific methods we could feed many more people per square mile than we do now, and probably at a less cost. But an immense amount of research will be needed before this is possible, and at present very little of it is being done.

[This series came to an end with the suppression of the *Daily Worker* in 1941.]

• 7 •

THE COMPARATIVE STUDY OF FREEDOM

The Comparative Study of Freedom[1]

THE first essential in any scientific study is a possibility of comparison. The measuring rod, the stop-watch, and the balance, are at the very roots of science. If our study of freedom is to have any practical results, we must try to tackle the question "Is A freer than B?" A may be a bus-driver in New York, and B a bus driver in Belgrade. Or B may be a corporation vice-president, a poet, or A's wife, in New York. In almost every case we find the question unanswerable. A has more freedom than B in some directions, but less in others. And the different kinds of freedom are incommensurable. A can, if he wants to, read the works of Marx, and can afford to go to the movies every night, which B cannot. But B can have a drink after midnight, and can afford a garden where his children can play, which A cannot. Who is to decide which is freer? Our best plan will be to specify different possible fields of freedom, so that we may be able to carry out comparisons within these fields. The overall summary will inevitably be subjective, but we can at least say that in some particular respect A is freer or less free than B.

Besides asking whether A is freer than B, we can ask the very important question whether A is becoming freer or less free in a given respect as the years go by. I would personally prefer to live in a country where freedom was increasing from a rather low level to one where it was declining from a high level. This again is perhaps a matter of one's own philosophy. But certainly such trends cannot be neglected.

Our classification of the fields of freedom will inevitably be somewhat arbitrary. And different classifications will overlap. Thus let us see what is meant by religious freedom, which most people in the United States honestly believe that they enjoy. It means legal freedom to believe any of a fair variety of doctrines, and to persuade others of their truth. There is also legal freedom to attack the religious doctrines of others up to a point. But you will find yourself in jail if you walk into a Catholic church and denounce the worshippers as idolaters or into a Protestant church and brand them as heretics. You may practise religious rites if they are not indecent or dangerous to life. But if you think you enjoy full religious freedom, try practising the Hindu Laya Yoga in New York and see how long the vice squad will leave you alone. Or bring over a crate of rattlesnakes and try the Hopi snake dance, and see how many laws you are breaking. As for the religion of the Latter-day Saints, which turned the salt deserts of Utah into a garden, one of its main practices, polygamy, has been prohibited by the Congress of the United States. The plain fact is that in any society there has at most been freedom for a group of religions which enjoin fairly similar standards of moral conduct. So it will be logical to divide up religious freedom under freedom to communicate ideas, freedom in sexual relations, various kinds of economic freedom, freedom of children, and so on.

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[1] This was written about Christmas 1939, before Hitler's conquest of Europe. I have not attempted to bring it up to date, if only because the result would be a bald comparison of the Fascist and anti-Fascist sections of the world.

Besides this horizontal classification, so to speak, there is a vertical classification of freedoms at different levels. The most fundamental level is the technical level. This may be Marxism, but it is also common sense. There could be no freedom of the press before printing was invented, because there was no press to be free or unfree. Thus a technical advance makes a new kind of freedom, and a new kind of bondage, possible. Given the technical possibility, there must in general be some legal restrictions. In no country is the press so free that incitements to murder the rulers of a state may be printed within it. Most people will support this restriction. Besides legal restrictions there are customary restrictions. Law permits me, but custom refuses me, the right to walk about the streets of London in

A tiger skin all striped and specked,
A scarlet tunic with sunflowers decked,
And a peacock hat with the tail erect.

In primitive societies there is no division between legal and customary restrictions, and in England too gross a breach of custom may turn out to be the crime of "insulting behaviour".

Economic restrictions on freedom are of primary importance. A vast number of technical possibilities are only open to a small minority. Very few people can own a steam yacht. Somewhat more can own a grand piano or an automobile. The all-important liberty of communicating ideas is enormously restricted by the fact that very few people are rich enough to own a daily newspaper. Further the development of technique tends to increase economic restrictions on liberty, simply because modern technical inventions embody a great deal more labour time than most of those of the past. Augustus Caesar could have more clothes and a larger house than an ordinary well-to-do Roman. But, unless he had wanted to have a pyramid built for him, he had few or no kinds of qualitative freedom beyond his special political freedom as emperor, which many other Roman citizens did not enjoy. Communists, who are often regarded as enemies of freedom, lay great stress on the fact that in practice many kinds of freedom, though not legally or customarily restricted, are economically restricted so that they are the privileges of a small minority. "Liberty", they claim, "is such a precious thing that it must be rationed." Under Socialism, as practised in the Soviet Union, certain liberties, for example the liberty to print or to voyage in a yacht, can only be practised by groups.

Finally we must consider internal restrictions on freedom. These may be at a variety of levels which in practice we rather arbitrarily divide into physiological and psychological, though every doctor realizes that the distinction is seldom quite sharp. Clearly a paralytic has less freedom than a man with full power over his muscles. But most people would regard a man with a wooden leg as freer than a cocaine addict or a victim of an obsessional psychosis which compels him to wash his hands twenty times a day. Beyond this it is harder to go. We all know people whose idea of "true freedom" is the following of some very narrow path. We can hardly define psychological freedom without venturing into philosophy. Freedom is something more than being able to do what one desires so far as the laws of nature permit. The drug addict with unlimited supplies of his drug is at least relatively unfree. His actions are controlled by a single motive, and lead to madness and death. A rich man who oscillates in a narrow orbit of office, bed, golf course, and annual holiday in the same resort is controlled by a narrow set of motives. He is relatively unfree because he has been so effectively conditioned by society that he has no will of his own. We need not however go to the other extreme, and hold up as an example of complete freedom the man who never keeps an appointment, or is faithful to one woman for a month on end. The so-called Bohemian can be described as the salve of his own caprices, and psycho-analysis would probably show that he is dominated by irrational motives of which he is unconscious.

As a geneticist, I see the problem in this way. Every human being, apart from monozygotic twins, has a unique genotype. For example my own genotype determines in me a subnormal capacity for music and a supernormal capacity for mathematics. Every genotype can be placed in many different environments. In some the individual will develop its powers, and act freely, in others this will not be so. If I had been born into a musical family and had no opportunity of learning mathematics I should have been less free than I am. Some genotypes, such as those which determine idiocy, can never attain to much freedom. A few, perhaps, can only find their realization in anti-social activity, though this is doubtful. But in any modern society a vast number of different activities are open. In so far as the choice between these activities is based on genotypes we can say that the society is free. Or to put it in another way, that society is freest in which each individual is pursuing those activities which give most scope to his or her innate abilities. I am perfectly aware that Aristotle defined happiness as "unimpeded activity". It may be said that I am speaking of happiness rather than freedom. The framers of the American Constitution realized that they were closely connected, though I suspect that happiness arises rather as a by-product from other activities than from its own deliberate pursuit.

But we cannot leave the matter on this merely biological level. I agree with Spinoza, Hegel, Engels, and Caudwell, to whose analysis of freedom in *Illusion and Reality* I am profoundly indebted, in defining freedom as the recognition of necessity. This is obviously true in the technical field. As long as men thought in terms of magic carpets, seven-league-boots, and angels who carried a house from Palestine to Italy, they could not begin to investigate the necessities embodied in the laws of physics. And until they did this, they could not build railways or automobiles. It is also true in the social and political field. A free man willingly obeys laws which he recognizes as just, that is to say necessary in the existing social context. And it is true in the psychological field. Here one is free so far as one understands one's own motives. In order to do this one must not merely examine one's own consciousness and so far as possible one's unconsciousness, but also the social system by which one has been conditioned. A man who accepts his mother's moral teaching as the voice of conscience is no more free than one who believes his sex hormones when they tell him that the last pretty girl he has met is the most wonderful woman in the world. The difference between a man and an animal is largely a matter of consciousness, and the difference between a psychologically free and unfree man is also largely a matter of consciousness.

The analysis which follows mainly relates to conditions before September 1939. War inevitably diminishes freedom, though much less is lost by defending one's country than by surrendering to aggression.

We can gain some insight into the general nature of freedom, by studying the simplest kind, namely freedom of movement.

Freedom of Movement

Imprisonment is the very negation of freedom. And freedom to go where one wants to is a very important kind of freedom, if only because one can escape from many kinds of bondage provided emigration to a freer country is possible. In the 19th century freedom of movement meant political freedom for many millions of Europeans who crossed the Atlantic to the United States. Today this is no longer so.

Freedom of movement depends in the most obvious way on technical inventions, such as roads, the riding of animals, wheels, harness, ships, railroads, automobiles, and aeroplanes. But this technical progress has had two effects. It has made legal restrictions on freedom of movement necessary, and it has led to economic inequalities. Bullock cart drivers on country roads in India do not seem to worry much about the rule of the road. A collision between two vehicles moving at 3 m.p.h. does not greatly matter. But somewhere about 10 m.p.h. a rule of the road becomes necessary. At 20 m.p.h. the energy liberated in a head-on crash is increased fourfold, and the rule becomes a matter of life and death. With higher speeds an elaborate road code, and special police to enforce it, are needed. That is to say some legal restrictions on freedom are the inevitable result of technological gains in freedom. In actual fact many of these legal restrictions result in real gains of freedom. I can drive much faster because drivers are restricted to one side of the road than I could if both were legal. And being a rational man I recognize the necessity for this restriction and gain in freedom by doing so.

I gain from other restrictions. The anarchist's ideal would, I suppose, be that anyone should be free to go anywhere. But I am actually freer because this is not so, and no-one has a legal right to enter my house except with my permission or with a warrant from the state. I should be still freer if I possessed a small private garden. But privacy can be carried too far; and it is carried too far when one man can enclose a hundred square miles of mountains for the purpose of shooting, and keep the public off them. In this case, as in many others, a considerable measure of equality is a requisite for freedom.

In practice, however, restrictions due to private property in land are less serious than other economic restrictions. Most people in Britain cannot move about as they would like to, even in peace time, for one of two reasons. Either they have a job, and only get very brief holidays. They may have saved up a good deal of money, but they dare not leave their job for fear of losing it. Or they are out of work, and cannot afford to travel. It is extremely difficult to arrive at any data, but I am inclined to think that the average man has a greater freedom of movement in the United States than anywhere else, and that this freedom is increasing most rapidly in the Soviet Union, where it is already fairly high. This, if correct, is due to the great development of transport and the high real wage in the U.S.A., and to the system of holidays with pay and workers' holiday resorts in the U.S.S.R. together with the fact that, as there is no unemployment there, workers tend to move very freely from one job to another.

It is also due to the large size of these two states. It is extremely difficult to leave one's country in search of work. And in an increasing number of states one cannot take any large sum of money out of it, so that in practice one can only travel abroad on state business, or business approved of by the state. The difficulties of foreign travel have been increasing for the average man since 1900. A rich man or a man with political influence can fly half round the world in a week. But I can remember when I could travel to most European states without a passport, whereas now I must often waste days in getting the necessary visas. Freedom in this respect is declining rapidly. The restrictions are certainly mainly due to economic causes. If, as seems likely, capitalism works progressively worse as the years pass, they will increase. And it will become increasingly desirable to be a citizen of a state covering a large area. For this purpose, by the way, the British Empire is not a state. One needs a passport or permit to travel to Eire or Canada from Britain.

As for the internal or psychological aspect of freedom of movement, we are slaves of custom to a most surprising degree. I spent three days this winter[1] going up the principal mountains of Wales in January, when they are covered with snow. I met exactly two other parties, though the Alps were crawling with Englishmen a year ago. And in certain types of society there is a strong ideological objection to travel. It is instructive to read the words which Dante puts into the mouth of Ulysses in hell. In one of the greatest passages in literature he describes a voyage of exploration to South Africa. And he repents it. Dante thought it was wicked to sail outside the straits of Gibraltar.

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[1] 1939–1940.

Very few people are explorers. A ban on exploration is no infringement of the liberty of the vast majority of people. Yet it may have a decisive effect on the history of a nation. The present expansionist drive in Japan is largely a belated attempt to overcome the handicap produced by the prohibition of foreign travel from 1636 to 1860. A blow to the liberty of a very small minority may be a blow to a whole people.

Freedom as a Consumer

Every human being is a consumer, even if not a producer. Every improvement in the technique of manufacture means a potential increase in freedom of consumption. So does every increase in real wages. Hence a comparison of the real wages in different countries tells us a good deal about the amount of this kind of freedom. Given the possibility of buying something beyond essential food, clothing, and shelter, freedom depends on the choice of commodities or services which is available, and the way in which the choice is actually made.

Legal restrictions may be few, as in the United States. Some people even think that lethal weapons are too easily bought there. They may be very serious, as in Britain during war, when many foreign-made goods are unobtainable owing to import restrictions. Over large sections of the world freedom of consumption has been drastically curtailed in recent years in order to promote national economic self-sufficiency, or autarky.[1] Apart from the question of books, which will be considered later, the most interesting problem is that of alcohol and drugs. Heroin is an unrivalled cough cure. I have several times taken large amounts of it for a considerable period without developing the faintest craving. Probably many others—perhaps a majority—would be none the worse if they could buy it freely whenever they had a cough. But there are enough potential addicts to justify its prohibition. Many people would prohibit alcoholic beverages because when they are sold freely some people abuse them. The attempt was a failure in the U.S.A., but may succeed in India. No prohibition of this kind should be regarded as desirable in itself. In fact, even if we agree that narcotics should not be sold freely, we may hope that our descendants will one day achieve sufficient psychological freedom to make this possible.

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[1] This is the correct spelling. Autarchy means something quite different, either self-government, or self-starting.

Custom, as well as law, plays a very big part in limiting freedom of consumption. There may be a standardized type of expenditure for a given class or profession. Thus until recently in England the ritual killing of foxes, grouse, salmon, and so on, at appropriate times of the year, was the hall-mark of respectability. At an earlier period a gentleman was expected to form a library. In the present age of transition England is probably unusually free in this respect, freer than the United States or France. On the other hand, as we shall see later, England is one of the least free countries in the world as regards discussion of the merits of consumable goods.

I think it probable that, owing to the high average real wage, the U.S.A. heads the list as regards freedom of consumption. This was almost certainly so during the epoch immediately preceding the 18th amendment and the economic collapse of 1929. Today there are so many families with no margin for buying beyond the barest necessities, that it is not so certain. The most rapid increase, though from a low level, is occurring in the U.S.S.R.

Freedom as a Producer

I personally enjoy nearly maximal freedom as to how I earn my living. I am paid to devote myself to a certain branch of science. I give a few lectures, and conduct research on problems which interest me. I have no fixed hours of work, and could take three months' holiday a year if I wanted. Besides this I earn some money by writing. But I do not have to support opinions of which I disapprove in order to earn my living. In fact I combine a decent remuneration with free choice. A few other intellectual workers are equally fortunate, but this number is rapidly diminishing, at least in Western Europe. How few paid manual or administrative workers enjoy this kind of freedom is shown by the universal demand for recreation, *i.e.* an alternative to work and to purely cultural activities, such as listening to good music; and by the fact that many people actually look forward to retiring from their work.

On the technological level, freedom of production is being rapidly strangled by the abuse of patent laws by monopolists. In many industries the small firm is hopelessly handicapped for this reason, quite apart from underselling and other activities of trusts.

Freedom as a producer means, in particular, freedom to choose your occupation, freedom to regulate its details, and unless the occupation is pleasurable, short hours of work and long holidays. Where there is widespread unemployment there can be no freedom of choice. A man with a job holds it like a bulldog, and does not try a number until he gets one to his liking. Under capitalism the workers have little opportunity of controlling their conditions of labour, though trade unions can accomplish something, and as a voter the worker may be able to help himself in a very indirect way. Where, as in Germany, neither method is available, illegal strike action may still have some effect. But direct control, as on a Soviet collective farm, or to a less extent in a Soviet factory, is only possible under Socialism or with peasant-proprietorship, which is however so inefficient economically as to restrict freedom as a consumer. Since hours and holidays are satisfactory in the Soviet Union, and unemployment does not exist, it appears that man is freer as a producer there than elsewhere. Since in all capitalist countries the independent producer is being more and more completely eliminated, the prospects of freedom for producers under capitalism do not seem to be bright.

Freedom as a Capitalist

In Dante's hell the sins of Sodom and Cahors were punished by a shower of slowly falling flames. But while the former class of sinners could escape them to some extent by running, the latter, who were usurers, or as we should say, financiers, were not allowed this privilege. However, usury is now permitted throughout Christendom, and this freedom has been an essential condition of the immense technical advances made under capitalism. These advances are slowing down because finance, which formerly served industry, is now strangling it.

In the Soviet Union the sin of Cahors is punished in this world, and so are other activities by which one man appropriates what, according to Marxist economics, is the value created by the labour of others. These activities include not only usury, but private trade and the employment of others for profit. The extreme form of the latter kind of exploitation, namely slavery, is of course almost universally illegal. The anti-Socialist claims that a very vital kind of freedom has been suppressed. The Socialist retorts that this kind of freedom, like freedom to drive on the wrong side of the road, is incompatible with the fullest technical progress, and that those natural powers which are developed in the capitalist can be used under Socialism in administrative posts. Outside the Soviet Union freedom of trade and investment is at present being effectively strangled in most belligerent and some neutral countries, except for those very large corporations which to a considerable extent control the states. It is hard to say where the capitalist is freest. I should hazard a guess that Argentina stood somewhere near the opposite pole from the U.S.S.R.

Sexual Freedom[1]

The minimum amount of freedom compatible with the reproduction of the race was enjoyed in Paraguay, where the

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[1] I have deliberately passed over the bewildering variety of sexual freedoms and bondages among primitive peoples.

Jesuits married off their Indian subjects without allowing a choice of spouses. Marriage between different groups of the population may be illegal, as in Germany and South Africa; it may lead to loss of employment, as when officers in the British Guards "marry beneath them"; or it may merely meet with social disapproval. Divorce and re-marriage are permitted in most countries, though not, for example, in Italy.

Extra-marital intercourse is rarely a crime, provided the parties are of a certain age. However, adultery is liable to severe punishment in India. And prostitution is criminal in many countries, though only in the Soviet Union is the man concerned punished more severely than the woman. Intercourse between two males is generally criminal (though not in Denmark) while that of women is rarely so. There is an equally bewildering variety in the customary limitations to sexual activity. In some circles within the same country monogamy is rigid, in others people normally "live in sin".

Almost everyone will agree that complete sexual freedom (which I suppose would include freedom of rape) is undesirable. Dante and I (to mention no others) would say the same of complete economic freedom. As regards legal sexual freedom Denmark probably heads the list of civilized states, while Eire ranks very low both as regards legal and customary freedom. The high cultural level, and the rarity of prostitution, in Denmark seem to show that such freedom may be harmless.

The main economic bars to sexual freedom are unemployment and gross disparity of income. Both of these may lead a woman to cohabit (whether in or out of wedlock) with a man whom she does not love, but whose income is more secure or larger than her own would be were she independent. It may similarly, but more rarely, induce a man to marry a woman for her money, or to live with her. This kind of check on freedom is probably most pronounced in the "Latin" nations and least so in the U.S.S.R.

A discussion of psychological checks awaits the development of a comparative analytical psychology.

Freedom to Communicate Ideas and Statements

This field of freedom includes freedom of speech, postage, and press. Technologically it depends on the inventions of writing, printing, telegraphy, radio, and so on, and on the development of arts such as poetry, drama, and cinematography. Incitements to certain crimes, and grossly indecent speech, writing, and art, are everywhere illegal. Further, one or more of the technical means of communication may be a monopoly of the state or of big business. Thus radio is directly controlled by the state almost everywhere in Europe, but not in the U.S.A. On the other hand the U.S. film industry is probably more trustified than those of some European nations.

The legal restraints may be by civil or criminal law. State prosecutions of men for speeches and writings are rather rare in England, though a Mr. Gott has several times been imprisoned for rude remarks about God, and ten years ago Communist speakers and writers were constantly being imprisoned. If Britain follows the example of France, this condition is likely to recur. But as compared with many countries Englishmen have a wide liberty of propaganda on general matters. For example in Germany the state forbids public statements in favour of racial equality, in the Soviet Union against it. In England both are permitted, provided that one does not say that the Germans are superior to other races.

In law there is extremely little freedom of political discussion in England. Sedition is defined as a word, deed, or writing calculated to disturb the tranquillity of the state, and lead ignorant persons to subvert the government and laws. In actual practice you can say a great deal in ordinary times, and print a great deal if you can get a printer. But in times of political tension the law may be enforced against the opponents of the government. Not of course against the opponents of the king. In 1936 the *Daily Worker*, the Communist party organ, was alone among daily papers in suggesting that Edward VIII might consult his own wishes regarding his marriage.

The undoubtedly seditious and possibly treasonable activities of the leaders of the Conservative party and the Church of England which led to that monarch's abdication were not, of course, interfered with.

In the Soviet Union the position is the opposite. Legally there is fairly complete freedom of speech. And actually there is a good deal. I have heard a man say that he could not see much difference between Stalin and Nicholas. A member of an important Soviet merely replied that there was quite a big difference. But on the whole custom is more stringent than law; so that there is somewhat less verbal criticism of the government than in England, though much more than in Germany or Italy, and perhaps more than in France. On the other hand the press has, in practice, less freedom in political matters than in Britain, though more than is often believed. In fact in Europe a press consistently opposing the government is only found in Britain, Switzerland, Belgium, Holland, and the Scandinavian countries. In Switzerland, Holland, and Belgium, this liberty is largely restricted. Thus among European nations, Britain enjoys considerable press freedom in political matters.

On the other hand English civil law makes any statement which could affect the financial interests of a well-to-do man very dangerous. For example a firm recently circulated a leaflet to the effect that I habitually used a medicine which they sell. I have never even seen it. I was told that the statement was not a libel on me. I attempted to deny it in the press, and even to suggest that the firm had in some measure departed from the strictest canons of morality in using my name. This suggestion was held to be probably libellous, and no journal would publish it for fear of an action. Finally one medical journal has consented to publish a bare denial, without any comment.

Similarly it is extremely dangerous to make any attack on the character of a rich man in public life. In consequence there is an entirely erroneous impression in many quarters that British politics are less corrupt than those of France or the U.S.A. Attempts have been made to start consumers' research in

Britain, as in the U.S.A. But the law of libel prevents this. Hence there has been a considerable deterioration in the quality of some British manufactured goods in recent years from the high standards of the 19th century.

To my mind the correct law would be fairly simple. Either statements of a general character about commodities, made without any evidence being adduced in their support, such as "Guinness is good for you", should be illegal. Or better, it should be legal to make such statements, and also equally unsupported statements, such as "Bass is bad for you and Worthington is worse".[1] At present, in commercial matters one can only praise, and not blame. Given the further fact that advertisers exercise a very strong influence over the policy of newspapers, so that in practice numbers of advertisements appear in the news columns, it will be seen that there is very little freedom of criticism in commercial matters.

This kind of criticism appears to be highly developed in the Soviet Union, particularly in such journals as *Krokodil* and *Vechernaya Moskva*. And indeed it is a necessity if Socialism is to be successful, since such criticism is an effective alternative to competition for sales between different firms, as a means for keeping up the quality of goods.

The freedom of the press is both legally and economically limited. In most countries libel, whether seditious or not, is more severely punished than slander. Everywhere technological progress is tending to improve the position of the big daily newspaper with a circulation covering a radius of 250 miles or so from its press, as against the small paper. Hence large capital is needed to start a daily newspaper, and wholesale distributive organizations can be used, and are used in England, to boycott any newspaper which criticizes the government too severely. In practice this method, and the influence of advertisers, means that in capitalist countries the circulation of Socialist journals is very small compared with the number of Socialists, even where such journals are legal. In the Soviet Union any attempt to start an opposition journal would probably meet with practical rather than legal difficulties.

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[1] I wish to make it perfectly clear that I make no suggestion as to the truth or falsity of these statements.

The position as regards publication of books is roughly parallel to that of the press. In Britain the law of libel is the main check. I have personally been prevented from criticizing fraudulent claims made for foods and drugs, from suggesting that certain doctors were incompetent, and from exposing pro-Nazi activities of British Conservative politicians and writers. The ban on indecency makes a scientific discussion of certain branches of human physiology rather difficult. But it is not a serious difficulty. On the other hand it is extremely severe in Eire, and used with great effect. Books published in Britain which are politically offensive to the government have long been prevented from entering certain parts of the Empire, and since the war their export to neutral countries has also been stopped. However, as regards book publication Britain is incomparably freer than most European states.

Other methods of disseminating opinion, such as the drama, are often subject to censorship. This is so in Britain. At the present moment for example, the censor, though he allows a measure of anti-war propaganda on the stage, forbids all reference to the help rendered to Hitler by members of the British Government in the years before the present war. On the other hand the censorship of indecent passages has been greatly relaxed of recent years, and almost all portions of the female body are now legally visible on the London stage. This is doubtless a gain of liberty for spectators, but hardly for girls who lose their jobs if they try to exercise the liberty to keep their clothes on. There is also a censorship of films in most countries. These forms of censorship are strongly supported by the Catholic Church, although of late years this body has probably disseminated more indecent (and untrue) stories than any other organization, mainly in connection with the Spanish war. As a matter of fact the Republican Government was rather puritanical.

The film censorship is everywhere strongly political. The radio is generally a state monopoly. At one time the British radio sponsored discussions on political, social, and religious topics, but these were always censored to some extent,[1] and were finally discontinued. It is now purely an organ of government propaganda. The United States radios are very much freer, though like the press, their general political policy is controlled by that of the advertisers. However, British listeners are certainly freer than those of many other countries. They are permitted to listen to the German radio (a freedom of which I have not myself taken advantage for some months), while Germans who listen to the British radio are imprisoned.

We see then that the liberty of the press, which was gained during the 19th century, has now been lost in most countries, partly by direct government action, partly by the use of the civil law, and partly by technological advances which have favoured centralization, and therefore control by Big Business. On the other hand the radio and cinema have never achieved so great a freedom as the press.

It is probable that the highest degree of freedom of communication of ideas exists in Denmark and certain of the United States, notably New York State, while the lowest degree is to be found in Germany, Italy and Japan. This kind of freedom is a very important one, but intellectuals are apt to speak and write as if it were the only kind. Actually an intelligent but reactionary government will allow a large measure of freedom of press and speech, being well aware of the fact that discontented people can "blow off steam" by this means without causing any serious disturbance, particularly in countries such as Britain with a long tradition of fairly free discussion. This is all the more the case if they can control the radio, the films, and the more widely circulated newspapers. For this reason freedom of speech and press, though correlated with political freedom, is not synonymous with it.

I have not yet mentioned the internal barriers to freedom of expression. And yet they are of profound importance. Some of us are no doubt congenitally incapable of original expression in words, music, photography, or any other art form. But most psychologists, and most ordinary people who have had sympathetic dealings with children, believe that the majority of human beings could make some real contribution to culture if they were put in the right environment. For some reason or other

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[1] See p. 24.

> Shades of the prison-house begin to close
> About the growing boy.

This is often due to economic causes. In the case of many a mute inglorious Milton, the poet says that

> Chill penury repressed their noble rage
> And froze the genial current of their soul.

But as the rich and the moderately well-to-do are almost as dumb as the poor, this is not the whole story. Probably most people could express themselves best in some communal activity such as symphonic music, drama, or dance. "Civilized" society is well organized for mass production of commodities and for mass consumption of standardized cultural commodities such as "best sellers", cinema films, and gramophone records. But it is far less organized than most primitive societies for collective artistic activity. Possibly the Soviet Union may be leading the way here. My own opinion is that the prospects for artistic activity are probably brightest in China, where art has never been thoroughly commercialized, and when peace and security are restored the natural artistic ability of the people will find a new scope. And the genuine respect of the Chinese for intellectual activity may make China in the future, as it has more than once been in the past, the intellectual's paradise.

Political Freedom

On no aspect of freedom is there more confusion than on that of political freedom. It is sometimes taken to mean government by natives of one's own country, rather than foreigners. Yet there is more political freedom (though not very much) in a province of British India such as Bengal than in a "native state" with an absolute ruler, such as Haidarabad or Nepal. It is also regarded as synonymous with democracy, and the latter with Parliamentary Government, though the Greeks who invented the word democracy (which meant government of the people, by the people, for the people, who did not however include women or slaves) had no parliaments. Finally it is taken to mean the right of stating opinions on political matters.

Nowhere in the world do these conditions exist in their entirety. The first type is only possible, in practice, for powerful nations. The members of smaller nations may easily find themselves in the position of citizens of Iraq, Esthonia, or Cuba, and this possibility increases with the development of transport. Actually they are better off as members of a larger aggregate in which they enjoy a measure of cultural autonomy and equality of citizenship. It is useless for Welshmen or Georgians to say that they are oppressed by English or Russians, when Lloyd George, a Welshman, was chosen to rule England in a critical hour, while Stalin, a Georgian, is the most important man in the Soviet Union. It may be that Welshmen would be freer if Wales enjoyed as much autonomy as Georgia, but actually the Welsh nationalist movement is not very strong. Where there is not equality of this kind, nationalist movements certainly make for increased freedom. This was, I think, the case in Eire, and is so in India. On the other hand the nationalist movement of the Sudeten Germans, which brought them under Hitler, diminished their freedom.

The second type of political freedom is claimed for all kinds of political systems. Even the Nazis claim that they enjoy "true" freedom, because Hitler expresses the political ideals of every true German. If so there must be a lot of untrue Germans. Now in the past there have been two main types of democratic government, namely the Greco-Roman and American types. In the former all citizens met together frequently, listened to orators, and voted for or against laws. In the latter they elect representatives at rare intervals, and these latter legislate. I call this system American rather than English, because when America became a democracy, the English Parliament was still elected on a very restricted franchise.

The obvious advantage of the first system is that the citizens decide matters directly concerning them, and of which they have immediate knowledge. Its disadvantages are, firstly, that voting is public and intimidation therefore possible, and that while well adapted for the government of a small city, it is impracticable for a state, let alone an empire. It was largely for the latter reason that it broke down when Rome acquired an empire.

The American or representative type is adapted for a large state, but has the disadvantage that representatives can and do break their election pledges, that the people can only vote at rare intervals, and that in practice they only have a choice between representatives of a few organizations (*e.g.* the two great American parties) whose policies are framed in secret by a small number of men. In the Soviet Union an attempt has been made to combine these two types of democratic mechanism. The village soviet has the advantages and disadvantages of a Greek assembly, whilst the supreme soviet corresponds to the American congress.

In theory this is an ideal system, but it is claimed that in practice all power is in the hands of the Communist party and its sympathisers. In practice, however, parliaments are also controlled from outside. In 1921 when Mr. Lloyd George, then Prime Minister of Britain, was displaying a certain radicalism in his financial policy, the *Financial Times* asked, "Does he and do his colleagues realize that half a dozen men at the top of the big five banks could upset the whole fabric of government finance by refraining from renewing Treasury Bills?" Certainly the Labour party realized this ten years later. "Upsetting the whole fabric of government finance" is not, of course, sedition!

In practice then the political liberty in a parliamentary democracy is largely at the mercy of Big Business. But not wholly so. Enough parliaments have annoyed Big Business to render it necessary to suppress parliamentary government over much of Europe. And not only in Europe. Newfoundland was unable to pay its debts to Britain. In consequence "the mother of parliaments" began to eat her children, and Newfoundland is now governed by British officials. It will be remembered that when Britain refused to pay its debts to America the British Parliament was replaced by an American governor-general!

The plain fact is that over most of the world such parliaments as survive are at least as subservient to Big Business as is the supreme soviet in Moscow to the Communist party. And even the most violent opponents of Communism will hardly claim that big business is democratic. Nowhere in the world is there political liberty as Jefferson conceived it, and as it actually existed in the days before monopoly capitalism developed. There is still a fair amount in parts of north-western Europe, the Soviet Union, the United States, the British Dominions, and some Latin American republics. On the whole it seems to be on the upgrade in the Soviet Union, China, and (with intermissions) in India, but stationary or on the down-grade elsewhere.

So long as the present class struggle goes on we cannot look for any great measure of political freedom even in the intervals between wars. Only a classless society which does not feel itself menaced either from within or without is likely to develop a complete political freedom in which discussion is both legally and economically free, and constitutionally elected governments are not overthrown by the violence or economic pressure of minorities. We may look forward to such a day, but we must not deceive ourselves into believing that comparative freedom of discussion, pleasant as it may be for intellectuals like myself, is synonymous with full political freedom. If the newspapers, radio, and other means of large-scale propaganda are mainly controlled directly or indirectly by Big Business, there is only rarely need for the forcible suppression of opposition. But the possibility of such suppression is always in the background. Under the Emergency Powers Act of 1939 any British citizen can be imprisoned without trial for an indefinite period and any newspaper can be suppressed without legal process. It will be very surprising indeed if this act is not used to strangle constitutional opposition.[1]

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[1] It was so used when the *Daily Worker* was suppressed in January 1941.

In England today political freedom has, *de jure*, no existence at all, even if *de facto* a good deal remains.

But if speech is still theoretically free (except when it is libellous, blasphemous, obscene, seditious, or insulting), this is because speech is an obsolete method of propaganda compared with radio and the press, and if our oligarchs control the latter they can afford to allow a rather moderate liberty of the former.

Religious Liberty

We saw at an earlier stage that religious liberty embraces a very wide field. In the sense of freedom to propagate religious and irreligious opinions and to perform rites which are not held to be cruel or indecent, it is fairly widespread. However, it is rarely complete. For example a conscript in Britain must register as a member of some Christian sect, or as a Jew, for the purpose of burial. Being neither a Christian nor a Jew, I exploited the small amount of liberty available to me as a soldier in 1914–18 by registering as an adherent of several different branches of Christianity, and of Judaism, on different occasions. Adults are not compelled to attend religious ceremonies, though they are hard to avoid in the army. But children can be and are compelled to do so in most countries, whilst in the Soviet Union I understand that organized religious instruction of children is forbidden. Thus in practice religious liberty is often like that of Germany after the Reformation, when each petty ruler was free to persecute his subjects if they disagreed with his theological opinions. Every British father is a princeling who can beat his children if they do not go to the church of which he approves, or go to one of which he does not.

Religious freedom is seriously compromised where religion involves ritual food or rest. It is very difficult for an orthodox Jew to rest on Saturday in England, though an orthodox Christian can now rest on Sunday in Russia unless he is employed in one of comparatively few occupations. In fact full religious freedom is impossible in an integrated community, simply because many religions can only be practised in their entirety when the vast majority of a people hold them.

The minimum of religious freedom is found in some Mahommedan countries such as Afghanistan, Persia, and parts of Arabia, and in Spain. It is rather low where there has recently been a violent reaction against religious intolerance, as in Mexico. It is below the maximum where any form of religion or irreligion is associated with the state, as in Britain, Italy, Sweden, and the Soviet Union. It may also be lowered where a religion is associated with foreign influence, as is Christianity in China. The Chinese, who are on the whole very tolerant in religious matters, have forbidden missionaries to attempt conversions to Christianity because such activity is thought likely to break up the national unity.

The highest degree of religious freedom is probably found in countries such as France and the United States, where the state is formally neutral in religious matters. But complete religious liberty is impossible, simply because all religious bodies are somewhat intolerant when their supporters control the government. They may be very intolerant like the Catholic Church, or very slightly so, like the Society of Friends, but they cannot from their nature be completely tolerant.

Freedom of Women and Children

The freedom of women has very little to do with the freedom of sexual relations. It is minimal in Mahommedan countries such as Arabia, Persia,[1] and Afghanistan, where all women are veiled, and those of the well-to-do classes are imprisoned. The impossibility of romantic love in such countries is compensated by homosexuality. It is maximal in countries such as the U.S.A. and the Soviet Union whose women not only enjoy legal equality with men, but are actually appointed to responsible positions such as that of ambassador. Indeed in the U.S.A. women's rights are perhaps over-exaggerated in connection with alimony for divorced wives, which enables a number of women to live an idle life at the expense of men. The same type of male subjection is found in a less developed form in England. Complete liberty and equality in this matter can only be achieved where work is available for every able-bodied adult.

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[1] Persia has progressed since I wrote.

Children enjoy little liberty where the family is patriarchal and their corporal punishment is commonly practised. State education generally makes for greater liberty for children, who often obtain a valuable political education by playing off their parents against their teachers. In Britain the children of the poor are far freer than those of the rich. A rich boy can be birched on his bare back at Eton up to the age of 19, and is then sent to a university where he is locked up every night until he is 23 or so. In fact ruling classes, the world over, are cruel to their own children. They have to be moulded into efficient members of the class, and must suffer in consequence. The Hitler-Jugend appears to be an attempt to inflict the English public school spirit on all the children of an unfortunate nation.

Complete freedom for children is impossible, but children can, in practice, be given freedom at a very early age if their training is directed to teach them the recognition of necessity. This means that they must be allowed to see and feel the consequences of their own actions, which will inevitably include some broken limbs and other injuries. If they are neither bullied nor pampered they develop human personalities at a very early age, and may be responsible citizens at the age of 17.

It is particularly difficult to compare different countries as regards the freedom of children. Child labour for long hours at monotonous work is no doubt a negation of freedom. But a boy doing interesting paid work for short hours is far freer than one in a school learning dull and often useless lessons.

Conclusion

We have ranged over a number of fields in each of which a greater or less degree of freedom is possible. Nowhere have we found the problem simple. This is partly because one man's freedom limits that of another, so that most kinds of freedom demand a measure of equality. If six bankers can control a state, it is time that the bankers had less freedom. In fact freedom in a class state means mainly freedom for one class, and that generally turns out to be a poor sort of freedom. In particular, if a ruling class is to be efficient, its members must be severely conditioned in youth. On the other hand the overthrow of the class state has meant a period of "dictatorship of the proletariat" with considerable restrictions on freedom, in the Soviet Union, and would probably do so elsewhere.

Three facts must be kept in mind. Even the freest of men has been so conditioned that he does not even notice the lack of some freedom which a man born in another place or time would regard as essential. This is why we are honestly apt to regard our own country as "The land of the free and the home of the brave", when we see the restrictions to which foreigners submit without a murmur. Curiously enough the foreigners often think the same when they visit our country. An intellectual who is making a fairly good living often regards himself as almost absolutely free. He is freer than many of his fellows. But he is only free because his product, whether in science, art, or literature, happens to find a market. When the market changes he finds that his freedom may be freedom to starve. However, the market is not a natural phenomenon, like the weather. It can be controlled, and although this involves some restriction of freedom, more and more people are coming to think that it results in a considerable increase of freedom on the whole.

Secondly, freedom is positive as well as negative. Man is a social animal, and human freedom can only be freedom in society, that is to say freedom to act as a social being. This is a hard saying, because it means that certain kinds of freedom, for example the freedom of a landlord to keep the public off a hundred square miles of mountain, or the freedom of a few bankers to overthrow a government, are anti-social. But it turns out that they are anti-social just because they restrict the freedom of others. The Greeks had a word for the man who used his freedom to turn his back on society. The word was "ιδιωτης", in English "idiot".

Thirdly, freedom is not static. It is always finding new fields. For example we are beginning to recognize the right of animals to freedom. It is now thought wrong to chain up a dog for life. Though the anthropomorphism of our ideas on this matter can be illustrated by the case of an eagle which recently returned to its cage in the London Zoo after two days of miserable liberty. Like everything that grows, freedom negates itself. The individual lover of freedom may join an organization which limits his own choice. Moreover he is more likely to find himself in prison than the man who always takes his cue from the majority.

And the same is true on a larger scale. A war or revolution fought for freedom means the temporary loss of a good deal of freedom. In the long run the loss is generally more than made good. But a social change, like a technological advance, always means a loss of some former liberty. We must realize that the freedom of one man may be the bondage of another, that the charter of liberty of one generation may form the chains of its successor.

I believe that a comparative study of freedom on the lines which I have indicated would do a great deal both to increase the respect between different nations, many of which, if far from ideal, have at least something to teach others in this important matter. It would enable us to see the beams in our own eyes before crusading to remove our neighbour's mote. And a historical study would show us the way in which freedom has actually developed, and help all lovers of freedom to strive for a real increase of that great good. The position of freedom in the modern world is so precarious that its preservation and extension require not only good will, but all the thought which we can devote to it. The problem of freedom is not a simple problem. Now as never before in history

Nôtre salut dépend de nôtre intelligence.

NOTE

This essay was written during the winter of 1939–40, for a collection of essays edited by Ruth Anshen, and entitled *Freedom, its Meaning*, published by Harcourt, Brace & Co., New York. I am encouraged to publish it here by the criticism which it received in an American magazine apparently devoted to justifying Big Business's ways to man. It is, of course, out of date. Freedom has been vastly reduced over most of Europe by Hitler's conquests, and inevitably to some extent in the United States since they entered the war. But a survey of freedom in 1939 is perhaps more valuable than one of freedom in 1944. I have only made very minor alterations, as the whole essay would have to be rewritten to bring it up to date.

But one point has become clear. The Nazis had bought, blackmailed, or persuaded numbers of men in every country to become their supporters. The only state which was taking adequate measures against them in 1938 was the Soviet Union. These measures, like other measures of national defence, involved certain restrictions on freedom, which appeared to many of its foreign friends to be excessive. They did so to me in 1939 when I wrote this essay. I do not now think that they were so. I have no doubt that these restrictions will disappear as the Soviet Union feels itself safer. This is made highly probable by the fact that in the Soviet Union alone among belligerent nations there have been very substantial increases of freedom during the war. In particular the Orthodox Church has gained the freedom, not merely to set up its own organization, but to found seminaries for the teaching of future priests, even though the doctrines taught in them are held by the members of the Soviet Government to be untrue and politically dangerous. This certainly bears out the view that freedom in the transmission of opinions is strongly on the upgrade in the Soviet Union.

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DIALECTICAL MATERIALISM AND MODERN SCIENCE

Dialectical Materialism and Modern Science

I. EVERYTHING HAS A HISTORY

IN this series of articles I propose to examine the question of how far the scientific discoveries of the generation which has elapsed since Lenin wrote *Materialism and Empirio-criticism* have verified the principles of dialectical materialism. These principles were formulated by Marx, and in much greater detail by Engels, and developed by Lenin and Stalin. "Nature", wrote Engels,[1] "is the test of dialectics", and dialectical materialism can only be accepted if it proves a guide not merely to an understanding of the development of science, but also to actual scientific research.

Its opponents say that it is a dogma to which scientific publications in the Soviet Union must conform, as scientific publications in mediaeval Europe had to conform to the current theology. But dialectical materialism does not state the nature of matter. "For the sole property of matter," wrote Lenin,[2] "with the recognition of which materialism is vitally concerned, is the property of being objective reality, of existing outside of our cognition." It states that matter is in a constant state of flux, that development occurs through a struggle of opposites, and so on, but it does not lay down where in nature such struggles are to be found. It merely prompts us to look for them, and helps us to understand them when discovered.

A certain number of scientists today are idealists, partly because our knowledge of cerebral physiology does not yet permit of a detailed theory of mind, but largely because it is abundantly clear that matter does not have the properties which were ascribed to it a generation ago by the majority of scientists, though not, of course, by dialectical materialists. Hence the idealists conclude that matter does not exist. This conclusion is, of course, very welcome in reactionary circles. If matter is defined as consisting of indestructible atoms it certainly does not exist. But thirty-three years ago Lenin wrote: "The recognition of immutable elements, of the immutable substance of things, is not materialism, but is metaphysical, anti-dialectical materialism." We shall see what has happened to the supposedly immutable atoms of 19th-century science.

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[1] *Anti-Dühring.* [2] *Materialism and Empirio-criticism.*

After Mendeleyev had formulated the periodic law, chemists gradually discovered new elements, until today all but one of the ninety-two elements between and including hydrogen, the lightest, and uranium, the heaviest, are known, and one or two heavier than uranium are suspected. Aston found that these elements are mixtures of atoms of slightly different weights. In fact there are not ninety-two, but several hundred kinds of stable (or more accurately nearly stable) atom, each atom consisting of a heavy nucleus round which from one to ninety-two much lighter electrons revolve. Rutherford showed that some naturally occurring atomic nuclei are unstable, and break down to yield lighter types of atom. But till recently these could be regarded as exceptions. In the last ten years, however, most of the elements have been bombarded with particles of high velocity, produced either by naturally radio-active substances or by the very intense electric fields, ranging to millions of volts, which modern developments of electrical industry have made possible. Such bombardments produce new types of unstable atomic nucleus. These are being discovered at such a rate that already probably more different kinds of unstable than of stable atom are known. The atoms of ordinary chemistry are only the survivors of a much greater number of less stable types, and even the stablest of them can be altered, and are constantly being altered, by cosmic radiation and other agents, though extremely slowly on our earth. But such processes must be relatively rapid in the interior of the sun and other stars, and act as the main source of their light and heat.

An atomic nucleus may be considered as built up of lighter particles such as protons, neutrons, and electrons. These particles can be studied, and their properties determined; and physicists naturally tended to regard them as "immutable elements" once the atom had proved not to be immutable. But they soon proved not to be immutable either. For example, there are electrons of positive as well as negative electric charge. They do not last long, for when a positive and negative electron collide, they pass over into a flash of high frequency radiation. And under certain circumstances radiation may generate a pair of electrons of opposite charges. "Contrary to metaphysics," wrote Stalin,[1] "dialectics holds that nature is not a state of rest and immobility, stagnation and immutability, but a state of continuous movement and change, of continuous renewal and development, where something is always arising and developing, and something always disintegrating and dying away." This view is completely borne out by modern physics, provided we realize that there is an immense range of different stabilities. The most transitory known objects, such as the particle called the meson, have an expectation of life of less than a millionth of a second. The stablest, such as the nuclei of ordinary atoms under terrestrial, though not solar, conditions, have an expectation of many thousand million years.

It may be answered that at least the laws of nature are stable, and that here at any rate immutability can be found. If so it is fairly clear that the universe is "running down", as Clausius believed, towards a condition of "heat death" in which the heat is evenly distributed, and that it cannot have existed for ever in the past. Thus a creation, or at any rate some breach of natural law in the past, must be postulated; and we are back at essentially the Newtonian theology, where the creator established eternal laws and leaves the universe to work out its own destiny. This fits in very well with the ideology of a bourgeoisie which realizes that there was a pre-capitalist period, but believes that the laws of capitalist economics are eternal.

Engels did not completely escape from this difficulty. He saw that thermodynamics, as formulated in his day, was self-contradictory, for the laws then given could not have held for ever. So he speculated concerning a building up of the lost heat of the stars into motion somewhere in the depths of space, which would allow the origin of new solar systems when our own has become cold. Thus eternity would be filled by cycles of more or less similar events, and the universe as a whole would have no history, being of the same general character as at present a million million years in the future or the past.

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[1] *History of the C.P.S.U.*

But some modern mathematical physicists, notably Lemaître, Dirac, and Milne, take a different view, according to which laws of nature change, and the general character of the universe therefore alters, though, of course, very slowly. Milne's cosmology is the most fully developed of these, and the most dialectical. Our sun is one star out of perhaps a million million in a system whose densest parts we see as the Milky Way. We shall deal with the development of stars in a later article. Hundreds of thousands of other galaxies are known. The more distant they are the redder their light. This may be interpreted as due to their moving away, or to the speeding up of atomic events, so that light which started a hundred million years ago is of lower frequency, and therefore redder, than light which starts from similar atoms today. Each interpretation demands a different time scale and a different geometry. On the scattering or "expanding universe" interpretation light frequencies and rates of chemical change are constant. But everything, including material objects, is expanding by about one two-thousand millionth part per year; and two thousand million years ago all matter was packed into an indefinitely small volume, and ordinary physical events, such as the rotation of the earth, took place in an indefinitely short time. On the other interpretation there is no expansion, and no slowing down of physical events. However geometry is not Euclidean. The two interpretations are not different theories of the universe, but different systems of measurement. For they lead to just the same predictions, though stated in different words, and there is no way of deciding between them. The latter is by far the more natural, as it takes ordinary standards, such as the metre and the year, as constant, or very nearly so.

On this interpretation the past and the future are infinite, but in the remote past, say fifteen hundred million years ago, chemical processes were so slow relative to physical that life as we know it was impossible, and the sun and other stars probably produced less heat than today, while in the remote future chemical processes will be so relatively speeded up as to render life still possible even if there is a marked fall in temperature. Milne points out that this development, this qualitative change in the nature of things, is due to the contradictions between the time scale on which radiation proceeds evenly, and that on which the movement of masses is an even process. No doubt this is not a final account of the matter. Milne's theory accords with Einstein's special theory of relativity, but not with his later general theory, some features of which have been verified by observation. Probably later workers will be able to combine the useful features of both Milne's and Einstein's theories. It is of great interest to find that a natural philosopher who is probably almost uninfluenced by Marxism should ascribe the qualitative development of the universe to the struggle between the wave-like and particle-like characteristics which are present in all matter. To this unity of opposites we shall turn in the next article.

II. THE UNITY OF OPPOSITES

In the physical theories of the 19th century the constituents of the world were rather sharply divided into two groups. On the one hand were particles such as chemical atoms, on the other the field between them, or ether, which was the carrier of waves of radiation, including light, radiant heat, and radio waves. The term "matter" was often reserved for the particles, even after it had been found that radiation has mass.

In the 20th century this distinction broke down. It was found that under certain circumstances radiation, including light and X-rays, was not absorbed continuously, but in definite units, or quanta. The amount of energy in a quantum is quite independent of the intensity of the radiation, but proportional to its frequency. Thus light behaves both as if it were composed of waves, and also as if it were composed of particles, the particles containing more energy in blue than in red light, and far more still in X-rays. The analogy to matter became still stronger when light was found to have weight as well as mass. That is to say it does not merely push an object which absorbs or reflects it, but is bent out of its path by a heavy body, as the French revolutionary Marat had believed, on quite erroneous grounds. The deflection predicted by Einstein and found by Eddington was much smaller than what Marat believed he had discovered.

Still more startling was the discovery that ordinary matter and electrons have wave-like properties. These are already of practical importance in connection with the electron microscope. This is used for examining objects too small to be visible by ordinary or even ultra-violet light. For example, it has shown that the grains in a developed photographic film have a complicated structure like that of a tangle of string. A beam of electrons is focussed by a combination of electric and magnetic fields which take the place of the lenses of an ordinary microscope. Such a beam behaves in many respects like a beam of light, provided the speeds of the electrons in it are uniform. It forms interference patterns with a suitable grating. And the wave-length of the electrons in the beam makes it impossible to photograph objects much smaller than this length, just as in the case of light. The frequency of vibration associated with an electron is constant, so the wave-length is inversely as the speed of the beam of electrons. Atomic nuclei have similar wave-like properties.

The union, both in matter and light, of these wave-like and particle-like properties, allows the development of an extraordinary degree of complexity even in systems such as a single atom, built up of very few constituents. Thus a hydrogen atom consists of two particles only, yet it can emit a spectrum in which more frequencies have been measured than the number of notes in a grand piano. The branch of physics which deals with these properties is called quantum mechanics, and might well be called dialectical mechanics. For, at least as at present formulated, it ascribes both to ordinary matter and to radiation properties which common sense regards as irreconcilable. But this contradiction allows of extremely accurate calculation of properties of matter and light which can be measured.

So much for small pieces of matter. Let us pass to phenomena on a larger scale. Consider, from the chemical point of view, an organism such as an adult man or insect, which is not growing or diminishing rapidly. Its intake and output of matter balance pretty exactly. But so do those of a steam engine or an internal combustion engine. The organism obeys the same laws as the engine as regards energy, but it differs in some fundamental respects, of which I only mention one. In the machine some parts last more or less unchanged through its "life"; others, such as washers, are occasionally replaced; whilst the lubricating oil is replaced still oftener, and the coal or petrol continually. In an adult animal it has long been known that the soft parts were constantly being renewed, proteins and other organic constituents being built up from the food, and then broken down and excreted. However, one would expect that at least the hard parts, such as bone, would be stable like the hard parts of a machine. Hevesy fed adult rats with sodium phosphate containing some artificially made radio-active phosphorus atoms. He found that after a few days some of these were present in the solid material of the bones. Growth had ceased, but exchange had not. Thus the living substance is a unity of anabolism, or building up, and catabolism, or breaking down of chemical compounds, and this even applies to the bones. The end of this unity of opposites is death. Once an animal is dead, it is possible to preserve it, and the atoms in its tissues mostly stay put for centuries.

If either tendency is carried too far, the unity is destroyed. A man may die of a disease like cancer, where too much material is built up in certain parts, or of a wasting disease such as diabetes, where not enough is built up. But all the manifold developments of life may be regarded as products of this struggle.

The struggle is very obvious within a community of plants and animals, or biocoenosis. All members of it, except plants (generally green) which live by photosynthesis, and saprophytic bacteria and the like, which live on dead organisms or excreta, live by killing or injuring other members. And yet these warring members form a unity which can be upset by altering the numbers of any of them. Thus if wolves eat deer which eat plants, there is a rough equilibrium, though numbers will fluctuate owing to good and bad seasons, epidemics, and so on. If the wolves are killed off the number of deer increases until it is limited by starvation. There are somewhat more deer, but mostly half-starved. Thus in practice some killing by beasts of prey is needed to keep the herbivora in health. Similarly cattle eat grass in a meadow. But they also eat and trample down larger plants which would choke the grass if it were not grazed. In fact an apparently hostile relation is often to some extent beneficial.

The experience of agricultural development in colonial countries has shown that the killing off of certain members of a community may easily upset the equilibrium by allowing another group of members to increase. There are violent fluctuations of numbers which generally at some point involve a destruction of green plants and impoverishment of the whole community like that which occurs in a capitalist trade slump. Within the unity of the group of species some pairs of species are on the whole antagonistic, some on the whole co-operative, but complete antagonism and complete co-operation are rare. There are obvious analogies with the State, but they must not be pushed too far, if only because the children of capitalists may become efficient workers, and workers may become capitalists, whereas many thousands of years would be needed before the lion would "eat straw like the ox". Still more important are the facts that man is characterized by production, so that human history is determined by economic as well as biological processes, and that he can to some extent consciously plan society, and thus ultimately escape from social forms which are determined by internal struggle.

Now let us rise still higher in the scale of magnitude, to stars. We know more than at the first sight would seem possible about the internal constitution of some stars at least, because the matter in them is not very densely packed, except perhaps at the centre; and though the temperature is very high, that is to say the atoms are moving very fast, their speeds seem to be no greater than we can obtain in a cyclotron. When atomic nuclei collide at these high speeds they sometimes unite, and heat is generated, as in ordinary chemical reactions, but in quantities which are about a million times as large per atom. The rate is sufficient to keep the sun shining at its present rate for many thousand million years. But the development of heat tends to make the stars expand, and the lessened density means fewer collisions, and therefore a slower heat generation. Similarly a decrease of temperature allows the star to contract under its own gravity, so that more collisions occur, and consequently more heat production.

In most stars these two tendencies are in equilibrium over short periods. But in one group of large stars, the Cepheid variables, they are not. These stars pulsate, expanding and contracting with periods of a week or so, and corresponding changes in light intensity. In case it be thought that I am dragging in "conflict" in the interests of Marxist theory, I may be permitted to quote from Gamow's popular *The Birth and Death of the Sun*: "The pulsations come as the result of a conflict between the nuclear and gravitational energy-producing forces in the stellar interior". And in the long run the equilibrium is not stable, in many cases at any rate. Stars undergo two types of explosion. One type produces an ordinary *nova*, a so-called new star of which one flashes up in our galaxy every few years. This is not really a new star, but a vast increase in the light of a previously faint one. The other type, or *supernova*, is far more brilliant. An explosion of this type occurs in our galaxy about once in a thousand years, and the exploding star is visible in broad daylight. Enough *super novae* have been seen in other galaxies to make it fairly clear that the explosion is much more intense than the ordinary *nova* explosion.

It seems probable that most, if not all stars, explode in one of these ways at least once in their "lives", and then change their structure considerably. It also seems that the explosions are not due to collisions or any other external agency, but to the internal struggle between the expansive and contracting tendencies, which, after millions of years of apparent equilibrium, produces a qualitative leap.

Many more cases might be given, notably the modern chemical theories of tautomerism and resonance energy, especially as developed by Pauling. But these examples should be sufficient to show that recent work is tending to verify Lenin's statement as to "the contradictory, mutually exclusive, opposite tendencies in all phenomena and processes of nature", and the view that the struggle between these tendencies is the cause of development.

III. QUANTITY AND QUALITY

The transformation of quantity into quality, and conversely, was regarded by Marx and Engels as a fundamental dialectical process. Marx states one aspect of it very clearly, when writing of the relation between small savings and capital. "Here," we read, "as in natural science, is verified the correctness of the law discovered by Hegel in his *Logic* that merely quantitative changes beyond a certain point pass into qualitative differences." Engels used the phrase to describe four slightly different facts. The "transformation" could either be an irreversible process actually undergone by a material system, as "when the taut rope parts under the pull", or a change found as we pass, in thought or perception, along a series of things which can exist at the same time, and which differ quantitatively, such as the chemical elements or the paraffin hydrocarbons, which are built up out of different numbers of the same fundamental units. He also applied it both to gradual reversible changes such as the melting of waxes, which have no definite melting point, and to very sharp ones such as the melting of ice. Doubtless a sudden transformation of an object or system shows the principle in its sharpest form.

The mechanics of Galileo and Newton were based on the ideas of continuous space, time, and motion; and the contradictions inherent in the latter, pointed out by Zeno and others, were ignored. The classical mechanics could explain some sudden changes. For example, it was clear why a stick suddenly fell when it was gradually pushed off a table, and it was hoped that all sudden changes would be explicable in this sort of way. However, classical mechanics have been unable to explain such simple phenomena as the breaking of a bar, or the boiling of a kettle. By explanation I do not, of course, mean merely verbal explanation, but numerical explanation, which would enable us to calculate, say, the boiling-point of water from simple properties of hydrogen and oxygen atoms.

During the present century it has become clear that only some of the laws of classical mechanics apply to atoms. They apply to large bodies consisting of many billion atoms simply because they are statistical consequences of the pooled motion of many atoms. This fact was predicted two thousand years ago in Epicurus' and Lucretius' doctrine of *clinamen*, according to which atoms showed a less regular behaviour than larger bodies. They do this because, under some circumstances at least, motion is only transferred to or from an atom in definite quantities, whereas according to classical mechanics it could be transferred continuously. In particular, angular momentum, or spin, is only transferred in definite units, or quanta, which are the same for all atomic events. An atom can exist in a number of different states, with different spins. And these states are qualitatively different. An atom with more than the minimum spin is liable to give out a flash of light. It is generally more active chemically than one with less spin, and so on. In fact, the transformation, and what is more, the abrupt transformation, of quantity into quality is, at least at the level to which modern physicists have penetrated, a fundamental property of matter. Many continuous changes depend on this sharp type of change, and not the other way round.

The action of the nervous system, both in sensation and in voluntary or reflex action, is based on the same principle.

Every cell in the nervous or muscular system, and very probably every gland cell, too, has a threshold of excitability, that is to say a minimum stimulus which is needed before it can do anything.

Further, the activity of a cell is seldom graded. A muscle fibre contracts with all its available energy, or not at all. A nerve fibre either does nothing, or transmits a unit impulse which is no stronger, and travels no faster, if the stimulus which starts it is greatly increased. Graded activity of an organ is possible by altering the number of units, for example muscle fibres, contracting at any moment, or the frequency with which each contracts. In the case of a muscle fibre a sufficiently rapid series of stimuli, each of which would cause a twitch, lead to a steady contraction.

On these principles we are beginning to understand some of the processes involved in simple sensation. A number of sensory nerves end in knobs which are sensitive to pressure. A very light pressure on such a knob may cause only a single impulse to travel along the fibre towards the brain. A moderate pressure will cause a series of impulses, at first frequent, then slowing down. A greater pressure is translated into a more rapid series, also slowing down in the end. The same seems to be true for more complicated sense organs. Our whole knowledge of the external world, and our whole action on it, depend on the numbers of nervous impulses going in and out through a few million nerve fibres. These impulses are all of the same nature, chemical changes with accompanying electrical potentials of a few millivolts. They do not seem to differ qualitatively according to whether they are destined to cause sensations of sound or warmth, pain or pleasure, or even to bring about secretion or motion. The whole qualitative richness of the external world, or of a philosopher's or poet's mind, is transformed into quantity at this level.

The change back to quality on the way inwards is only partly understood. But it depends on thresholds which vary qualitatively as well as quantitatively. Each sensory nerve fibre connects with a number of cells in the spinal cord or brain, from which more fibres arise. A large number of impulses arriving at once along fibres from the same part, as when a blow is given, will excite the relatively sluggish cells concerned in a reflex action such as withdrawing a limb. Even strong stimulation of a single end organ in the skin can probably never start a reflex, and rarely reaches consciousness. Repeated impulses along one fibre will stimulate nerve cells which do not respond to single stimuli. Simultaneous impulses from a number will stimulate cells which do not respond to repeated stimuli from one fibre, and so on. Thus as we travel up the central nervous system towards the cerebral cortex the nervous activity comes more and more to represent patterns of stimuli in the external world. And finally in the cerebral cortex the relevant patterns correspond to material objects, words, and so on, so that we are directly aware of these, and not of the series of points of pressure or colour, or isolated elements of sound, into which some philosophers have tried to analyse our perceptions.

The transformation of quantity into quality on the way out, involved in skilled muscular movement, will perhaps be easier to investigate, but has been less studied. This is probably because physiologists have so far been under the influence of philosophies which regarded sensation as more important than action—as indeed it is for a leisured class. When we know in detail how the impulses coming down the arm nerves are translated into skilled hand work we shall probably obtain many clues to the converse transformation of quantity into quality in the brain.

The transformation of quantity into quality is very clearly shown in the course of evolution. Suppose the linear dimensions of an animal to be increased ten times, but its shape unchanged, then its bulk is increased a thousand times, but its surface only one hundred times. Thus if its chemical changes go on at the same rate, each area of gut must pass in ten times as much food per day, each area of lung or gill ten times as much oxygen, and so on. So the animal will only be able to live an active life if the area of the gut is increased by coiling it, throwing its surface into numerous projections, and so on.

Similarly the gills and lungs must become more complex, the circulation must become more efficient, and so on. In fact, it is probably truer to say that the most advanced animals are complicated because they are large, than that they are large because they are complicated.

Many more examples might be given, but I will end on a personal note. It is often said that Marxism is somewhat of a pose in scientists who adopt it, and that it does not influence their research. During the 19th century it was found that many gases could be liquefied by cold, and Engels, among others, predicted that a quantitative change of temperature would lead to a sharp qualitative change of state in all of them. This has now been found to be the case. However scientists, whether or not they are materialists, were almost all unduly mechanistic. Qualities such as taste or smell are thought to be less real than quantitatively measurable characters such as density. Now a gas such as hydrogen sulphide with a strong smell, or carbon dioxide with a strong taste, is inodorous and tasteless until it reaches a certain concentration, which is the threshold for the human sense organs. The threshold is best measured as partial pressure. Hydrogen sulphide is first smelt at a pressure of about a millionth of an atmosphere, carbon dioxide first tasted at a pressure of about a fifth. It is obvious that a gas such as oxygen, which has no smell or taste when breathed pure at a pressure of one atmosphere, may yet be perceptible at higher pressures.

It was not, however, obvious to a number of scientists who had been at a pressure of six atmospheres, corresponding to 170 feet of sea water; because they recognized the transformation of quantity into quality in special cases, but not as a general principle, or believed in the "lesser reality", to use a sarcastic phrase of Lenin's, of smell and taste as compared with shape and rigidity. So I was the first person to taste oxygen. At six atmospheres' pressure it tastes like rather flat ginger beer. At higher pressures it may perhaps develop a smell. This simple example shows that the law of the transformation of quantity into quality is not merely a convenient summary of a number of previously discovered facts (though both the quantum theory and the thresholds of nerve cells were discovered after Engels' death), but a living and fruitful guide to actual scientific discovery.

IV. NEGATION OF THE NEGATION

The contradictions embodied in a system commonly lead to a struggle, which results in development. Where we can follow the detail of this struggle, we find that the formula of the negation of the negation often expresses the final phase, which leads to the sudden "emergence" of novelty, with remarkable accuracy; as in Marx's description of the transition to Socialism, "The expropriators are expropriated".

We do not know enough of the detail of how unstable atoms or molecules undergo sudden change to say how, if at all, this principle applies. But it certainly applies to the familiar irreversible physical changes such as the breaking of a stick or metal bar which is overbent, or a rope or rubber band which is overstretched. Under no external strains, or slight strains, the molecules of a solid are commonly arranged in a system of minimum energy (like a stone lying at the bottom of a bowl instead of being perched in a less stable position). They may be arranged in crystals, as in cast iron, or fibres as in wood. Now a strain such as bending or pulling upsets this arrangement. The stable configuration of molecules is negated. In its early stages this process is reversible. The solid regains its former shape if the force on it is removed. But at a certain point the negation is abruptly negated. The solid breaks, and each part returns to a stable configuration of molecules. There may of course be intermediate stages of permanent set. This is of course a crude example. In other cases the negation of the molecular arrangement leads, after a more or less chaotic period, to a new one. Thus when ice near its melting point is compressed, it first melts, that is to say the molecules lose their orderly arrangement, but at about 6000 atmospheres it passes into another solid form, ice-VI, in which the molecules are more densely packed than an ice-I, the well-known form.[1]

A beautiful example of a negated negation is found in the modern geological theory of the formation of certain mountain ranges, such as the Alps. These occur in regions of folding where the earth's crust, by cooling or continental movement, is under lateral pressure. The first effect of this pressure is to cause a downward folding, such as occurs, for example, off many of the coasts of the Pacific, where there are deep oceanic troughs. These are filled with sediments which form rock. As the folding progresses these sediments are brought up again above sea level. Being lighter than the granite of which the continents are largely composed, they can form comparatively stable mountain ranges of considerable height, whereas a range consisting of heavier rocks would gradually sink when the mountain-building forces no longer acted. Thus the downfold, or geosynclinal, is transformed into its opposite, a mountain range.

But the negation of the negation is most strikingly shown in the field of biology. The most primitive organisms merely grow and divide. If they break down the large molecules of their bodies into smaller molecules which are excreted, this is a negation of their life process. But in the higher animals the breakdown of relatively large molecules, such as glycogen and adenosinetriphosphoric acid, is the immediate source of the energy of muscular movement, which enables them to get food which is quite unavailable to the simplest organisms. The negation of growth thus negates itself.

The evolutionary process depends on the struggle between variation and selection. As Engels pointed out, either may be taken as positive. However, the following treatment is perhaps the most consonant with modern biological ideas.

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[1] I have been criticized for writing dogmatically about "hypothetical" arrangements of molecules. In a full-scale book I might have summarized the evidence on which my statements are based. Here I can only remark that it is much stronger than was the evidence for the Copernican theory in Newton's time. And as I have repeatedly staked my life on the substantial correctness of molecular theory, I can claim that my thinking on it is "this-sided".

Normally like produces like, or nearly so, whether in growth, as when one potato or geranium produces many vegetatively, or in sexual reproduction. More accurately, like responds alike to a similar environment. Some variation within the progeny of a single organism or pair is merely due to the different responses of fundamentally similar organisms to different nurtures. Some, including sex differences in most species, is due to hybridity, that is to say to the fact that the original organism considered, or one of them, was formed by the union of germ-cells whose nuclei were unlike. But some variation is due to mutation, a radical change which may produce entirely novel types, and which leads to hybridity in later generations, and thus furnishes the raw material for all kinds of heritable variations. Mutation is in fact the negation of heredity. The novel types produced by mutation very rarely prove fitter than the original type. So natural selection generally eliminates them, though occasionally one may spread through a species and transform it. The negation is usually negated. But this does not give us a uniform species, for many disadvantageous mutants are eliminated quite slowly. On the contrary, as Tsetverikov first showed, and Dubinin and others, including Gordon, Philip, Spurway and Street in my own laboratory, have proved in greater detail, it leads to a state of affairs where the species is permeated with small variations, more or less harmful one at a time, but sometimes beneficial in suitable combinations, or potentially useful if external conditions change. Fisher believes that the struggle between mutation and selection causes slow changes in a species which are not due to environmental pressure, and thus gives an internal cause for evolution such as has been attributed to vital urges and the like. It certainly makes a species more variable and plastic than it would otherwise be.

Evolution proceeds by the same method in many details. Every major change of environment negates the former normal conditions of the organism. Thus when our fish ancestors came out of water they could not move quickly on land. They breathed with difficulty, saw badly, were subject to rapid temperature changes such as do not occur in water, and so on. It took many million years to negate these negations. They were negated by the development of such organs as legs and lungs, by large changes in the eyes, and finally by mechanisms for regulating the temperature. These, when they were perfected, enabled the mammals and birds to colonize even the arctic, and rendered many other developments possible. Man has recently developed a large brain which, among other things, has cramped his teeth and bent his nasal passages. The teeth and nose are among the weakest and most readily infected parts of our bodies. Natural selection is likely to negate this weakness in our remote descendants.

Finally the negation of negation is extremely typical of the development of scientific theory and practice. Here at least Hegel was not standing on his head. His account of the dialectic needs far less modification in connection with human history than with nature. The dialectical development of mathematics was described by Engels,[1] to whom readers are referred. At the end of the 19th century the atomic theory in chemistry was generally accepted, though Ostwald and a few other chemists stood out. But the number of atoms in a gram was uncertain within a factor of a hundred or more. Then Thomson showed that electrons could be detached from atoms in a gas, and Rutherford found that atoms broke up. This negated the atom as an "eternal brick", but made it possible to count atoms with great accuracy, since individual electrons or atomic explosions produce effects which are visible with a microscope..

We have seen how widely Marxist principles are applicable to modern science. Some scientific workers admit this, but add that Marx and Engels only formulated principles which good scientists follow instinctively. Even if this were the whole truth, their formulation would have been a very great step forward. But actually an individual scientist will often turn out to be quite dialectical in his treatment of some particular problem, say resonance energy or reflex action, but crassly mechanistic or idealistic when dealing with other questions, including his own social and economic position. For this reason every scientific worker will be aided in his work by a study of such classics as *Feuerbach*, *Anti-Dühring*, *Dialectics of Nature*, *Materialism and Empirio-criticism*, and chapter 4 of the *History of the C.P.S.U.* (B). He must remember that they must be studied not as eternal truths, but in their historical setting; not as dogmas, but as guides to action. If he does so he will not merely improve the quality of his research and teaching; he will find himself no longer a mere individual passively involved in the torrent of contemporary history, but actively engaged in changing society and shaping the world's future.

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[1] *Dialectics of Nature.*

V. MATERIALISM AND ITS OPPONENTS

We shall not be able to counter the arguments which philosophers and scientific workers bring against materialism unless we understand not only their social origin but the considerable measure of truth behind them. Lenin[1] wrote that "Philosophical idealism is only nonsense from the standpoint of crude, simple, metaphysical materialism. On the other hand from the standpoint of dialectical materialism, philosophical idealism is a one-sided, exaggerated development of one of the features of knowledge into an absolute, divorced from matter. . . ."

In each generation the undialectical materialists try to explain everything in terms of matter and motion described in terms which may be adequate for school physics, but are quite inadequate even for the very abstract view of the world needed by the laboratory physicist. No wonder they are of little use to the biologist, and still less to the psychologist. The syllogism of the idealistic biologist runs, "Matter has the properties which were taught to me at school. These properties will not explain life, let alone mind. Therefore matter does not exist, or at any rate there is a spiritual world independent of matter."

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[1] *On Dialectics.*

Because the first and third clauses are untrue, we must not forget that the second is true. Many of the idealistic writings of contemporary scientists (though not all) are of real value as criticisms of mechanistic materialism.

In the ancient Greek world the class which was rising when philosophers began to study the world was a class of merchants. They required arithmetic for their calling, and it was natural that Pythagoras, who, according to Aristoxenus, "was the first to develop mathematics beyond the necessities of trade", should identify reality with number. The rising bourgeoisie of the seventeenth century were concerned with navigation, ballistics, and mining, especially the operations of lifting solids and pumping water. For Newton and his followers, including the philosophical school of Locke, matter had extension and mass, but its other properties, such as colour, taste and smell were "secondary" and illusory. The Newtonian or mechanistic conception of nature only broke down within the sphere of physics after over two centuries, and still dominates scientific thinking because a post-Newtonian theoretical physics, including relativity and quantum mechanics, is only now being framed.

We can get some idea of what this physics will be like by studying the mathematical framework, which is the scaffolding, so to say, for the new building. The old Greek merchants had been largely concerned with the simplest possible relations between material objects which are symbolized by the word "and". Number, weight, and bulk are additive. Two and three are five, two ships and three ships are five ships, two pounds and three pounds are five pounds. Newtonian physics involved more complex relations. Thus the gravitational force between two bodies is proportional to the product of their masses. The gravitational force between a two-pound weight and a three-pound weight is not five but six times the force between two one-pound weights at the same distance. A particle was supposed to be fully described by three numbers representing its position in space, three more representing its velocities in three perpendicular directions, and others representing its mass, electric charge, and so on. But for modern quantum mechanics as developed, for example, by Dirac, a particle is represented by an operator. An operator is a mathematical activity, an adverb, as it were, in the mathematical language, which converts one function into another. Thus the operator $\frac{d}{dx}$ converts x^2 into $2x$, $\sin x$ into $\cos x$, and so on. The operator E converts x^2 into $(x+1)^2$, $\sin x$ into $\sin(x+1)$, and so on. The action of the much more complicated operator representing a particle on a function representing waves or vibrations gives the most accurate numerical predictions so far available as to how the particle will behave. The substitution for a self-existent particle of something which can only be described in terms of its actions on other things is clearly a step in the direction of dialectical materialism.

We cannot tell in detail what the new world picture will be like. As Lenin[1] put it: "It is, of course, absurd to say that materialism ever . . . professed a 'mechanical' picture of the world, and not an electro-magnetic or some other, immeasurably more complex, picture of the world as matter in motion". But we can be sure that on the one hand it will fit the mathematical scheme which is now being developed, as the picture of the world in terms of indestructible particles with no properties but position, size, inertia, attraction and repulsion, fitted Newton's and Laplace's mathematical scheme. And we can be nearly sure that in doing so it will take account of qualities such as colour, sound and smell, which are "secondary" and unreal for mechanistic materialism. It is noteworthy that just as Planck and Einstein showed that light behaved, not only as if it were composed of waves, but of particles, the Soviet physicist Frenkel has applied the same treatment to sound, some of whose properties are most readily calculated if it is regarded as consisting of particles which he calls phonons. Thus the new physics will not merely be more accurate quantitatively than the old. It will give a more concrete account of the world, including many of the qualities which, according to dialectical materialism, but not to idealism or mechanical materialism, really exist in the real world.

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[1] *Materialism and Empire-criticism.*

Eddington has succeeded in making some deductions concerning the general nature of physical systems, for example the ratio of the masses of a proton and an electron, from the fact that they are capable of being experienced, and draws the idealistic conclusion that their whole being consists in being experienced. Not all his colleagues agree with his deductions; but even if they are correct, the capacity of matter for acting on our sense organs, and thus being experienced, is only one of its physical properties, and Eddington might as well have started off from one of the others. If men were immaterial souls somehow watching the external world through the sense organs, we should have no guarantee that matter was at all like our perceptions of it. But actually we have acquaintance with matter in two different ways besides direct perception through the sense organs. As Marx never tired of pointing out, we act on it as well as perceiving it. In so far as our actions are successful, this guarantees that our perceptions are not illusory, at least in some respects.

We have also a third source of information. If our brains think and feel, then every fact about human consciousness is a fact about matter, namely the matter of our brains. True, we do not perceive our brains directly, but we learn facts about them which we could never learn by direct perception. We learn that some material systems can feel, think, and will. Now this fact has been the basis of two distorted views which are sometimes held by the same person. One is idealism, the theory that feeling, thought and will are the reality of which matter is the appearance. If our sensation and ideas are images of matter, it follows that matter is like them. If your photograph is like you, you are like your photograph. Similarly, some relations between material objects or events are like thought, and force is like will.

The question is, which is the model and which the copy? Modern followers of Mach, such as Carnap, say that the question is meaningless; the world can be "logically constructed", taking either matter or mind as primary. If Carnap were an eternal being, the only one of his kind, he would be right. But Marx and Engels first saw that the question can only be answered on social and historical grounds. If you are in doubt which of two things is a model and which a copy, find out which was there first. Matter was there before men or any higher animals, probably before life at all. Hence matter is the model, and mental events the copy. And hence the extreme philosophical importance of evolution, of which, by the way, an account could only be given when the development of mines and canals had revealed the fossil record.

The other distortion, mysticism, which is associated with some forms of idealism, is the theory that important information about the universe can be gained without any sense impressions, after withdrawing the mind from the external world by ritual, meditation, or chemical substances such as nitrous oxide. This is opposed to the view that "there is nothing in the intellect which was not first in a sensation". Historically mystics have generally begun by intuitions of the truth of some religion. But the greater mystics have often stated that the God with whom they claimed unity was not a person. In fact many of them were more than half-way to atheism, and some Buddhist mystics have been complete atheists. Mystical experience is a fact, but it is primarily a fact about the brain. It may give some information about the universe, but this information will be even further from the truth than that of our senses. Our senses tell us that the sun goes up and down every day, that mustard is hot, that a stick thrust into water is bent, and so on. Mystical experience is still more fallacious. The theories based on it are sterile flowers, as Lenin said. But they are rooted in reality. The reality behind mystical experience is perhaps the perception of a unity which may have been a commonplace for a member of a primitive tribe, and will perhaps be equally obvious to a member of the Communist world society of the future, but which even members of the Socialist society of the U.S.S.R. can only grasp in part. In a class society this reality can only be expressed in a highly mythological form.

Thus a radical, dialectical, materialist need not, and indeed must not, neglect any parts of human experience. On the other hand, until the physiology of the brain has been developed a great deal further, the materialistic account of consciousness must be extremely sketchy, and Marxism will be mainly useful in describing its social relations rather than its physical basis.

It is important to refute the widely held view that idealism makes for good conduct. The moral implications of idealism were, I believe, stated once for all in *A Little Boy Lost*, by William Blake:

Nought loves another as itself,
Nor venerates another so,
Nor is it possible to thought
A greater than itself to know.

Idealists all agree with the last two lines. How nearly they agree with the first two is shown by their attempts to justify virtue by explaining that I am "really" identical with my neighbour, generally because both of us are identical with God or the Absolute. Idealists can, of course, be virtuous; but their idealism often helps them to the comfortable belief that other people's sufferings are not real; and they cannot reach the peak of virtue of a materialist who deliberately gives up his or her life, without hope of a future life, for a great cause, as hundreds of thousands of materialists are doing today in the Soviet Union.

Above all idealism is dangerous in the political field, where it leads to the liberal belief that good intentions will make an out-of-date economic and political system work, and the anarchist belief that they are enough without any political system at all. To combat idealism we must understand its strong points as well as its weak ones, and be able to explain to idealists that dialectical materialism embodies the really valuable and fruitful elements in their philosophy.

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